PHYSICS

CLASS IX

House of Physics Publications

Unit 1: Physical Quantities and Measurement

Textbook Exercise Questions

1.1 Encircle the correct answer from the given choices.

i. The number of base units in SI are:

(a) 3 **(b)** 6

(c) 7 ✓ **(d)** 9

ii. Which one of the following unit is not a derived unit?

(a) Pascal **(b) kilogram ✓**

(c) Newton **(d)** watt

iii. Amount of a substance in terms of numbers is measured in: (LHR 2011)

(a) Gram **(b)** kilogram

(c) Newton **(d) mole ✓**

iv. An interval of 200 μs is equivalent to: (LHR 2015)

(a) 0.2 s **(b)** 0.02 s

(c) 2×10^{-4} s ✓ **(d)** 2×10^{-6} s

v. Which one of the following is the smallest quantity?

(a) 0.01 g **(b)** 2 mg

(c) 100 μg **(d) 5000 ng ✓**

vi. Which instrument is most suitable to measure the internal diameter of a test tube?

(a) Meter rule **(b) Vernier callipers ✓**

(c) Measuring tap **(d)** screw gauge

vii. A student claimed the diameter of a wire as 1.032 cm using Vernier calipers. Up to what extent do you agree with it?

(a) 1 cm **(b)** 1.0 cm

(c) 1.03 cm ✓ **(d)** 1.032 cm

viii. A measuring cylinder is used to measure:

(a) Mass **(b)** area

(c) Volume ✓ **(d)** level of a liquid

ix. A student noted the thickness of a glass sheet using a screw gauge. On the main scale, it reads 3 divisions while 8th division on the circular scale coincides with index line. Its thickness is:

(a) 3.8 cm **(b)** 3.08 cm

(c) 3.08 mm ✓ **(d)** 3.08 m

x. Significant figures in an expression are:

(a) All the digits

(b) All the accurately known digits

(c) All the accurately known digits and the first doubtful digit ✓

(d) All the accurately known and all the doubtful digits

xi. Identify the base quantity in the following:

(a) Speed **(b)** Area

(c) Force **(d) Distance ✓**

1.2: What is the difference between base quantities and derived quantities? Give three examples in each case.

Base Quantities	Derived Quantities
The quantities on the basis of which other quantities are expressed are known as base quantities. **Examples** Length, time, mass	Physical quantities which can be described in terms of base quantities are known as derived quantities. **Examples** Force, area, volume

1.3: Pick out the base units in the following:

Joule, Newton, kilogram, hertz, mole, ampere, meter, Kelvin, coulomb and watt.

Base units

- Kilogram (unit of mass)
- Mole (unit of quantity of substance)
- Ampere (unit of electric current)
- Metre (unit of length)
- Kelvin (unit of temperature)

1.4: Find the base quantities involved in each of the following derived quantities:

(a) Speed (b) Volume (c) Force (d) Work

Ans: (a) <u>Speed</u>

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{\text{Length}}{\text{time}}$$

So base quantities involved in speed are length and time.

(b) <u>Volume:</u>

$$\text{Volume} = \text{length} \times \text{width} \times \text{height}$$

$$= \text{length} \times \text{length} \times \text{length}$$

So base quantities involved in volume is length.

(c) Force:

$$\text{Force} = \text{mass} \times \text{acceleration}$$
$$= \text{mass} \times \frac{\text{Change in velocity}}{\text{time}}$$
$$= \text{mass} \times \frac{\text{distance}}{\text{time} \times \text{time}}$$
$$= \text{mass} \times \frac{\text{Length}}{\text{time} \times \text{time}}$$

So base quantities involved in force are length mass and time.

(d) Work:

$$\text{Work} = \text{Force} \times \text{distance}$$
$$= \text{mass} \times \text{acceleration} \times \text{distance}$$
$$= \text{mass} \times \frac{\text{Change in velocity}}{\text{time}} \times \text{distance}$$
$$= \text{mass} \times \frac{\text{distance}}{\text{time} \times \text{time}} \times \text{distance}$$
$$= \text{mass} \times \frac{\text{Length}}{\text{time} \times \text{time}} \times \text{Length}$$

So base quantities involved in work are length, mass and time.

1.5: Estimate your age in seconds. **(LHR 2014, 2015)**

Ans: Let present age = 15 years

$$= 15 \times 365 \text{ days}$$
$$= 5475 \text{ days}$$
$$= 5475 \times 24 \text{ hours}$$
$$= 131400 \text{ hours}$$
$$= 131400 \times 3600 \text{ second}$$
$$= 473040000 \text{ second}$$

1.6: What role SI units have played in the development of science? **(LHR 2013)**

Ans: With the development in the field of science and technology, the need for a commonly acceptable system of units was seriously felt all over the world particularly to exchange scientific and technical information. To fulfil this need a world-wide system of measurements called international system of units was adopted.

1.7: What is meant by vernier constant? **(LHR 2014, 2015)**

Ans: "The difference between one small division on main scale and one vernier scale division is called vernier constant. This is the minimum length which can be measured accurately with the help of a vernier callipers. That is why it is also called the least count of vernier callipers".

1.8: What do you understand by the zero error of a measuring instrument? (LHR 2014)

Ans: The error in a measuring instrument due to non-uniform or wrongly marked graduation due to which a measurement may be less or greater than actual measurement is called zero error of the measuring instrument.

1.9: Why is the use of zero error necessary in a measuring instrument? (LHR 2013)

Ans: If a measuring instrument has a zero error, readings taken by it will not be correct. By knowing the zero error first, necessary correction can be made to find the correct measurement. Such a correction is called zero correction.

1.10: What is a stopwatch? What is the least count of a mechanical stopwatch you have used in the laboratories?

Ans: "An instrument used to measure the time interval or specific period of an event is known as stop watch". Least count of mechanical stop watch is 0.1 second.

1.11: Why do we need to measure extremely small interval of times?

Ans: We need to measure extremely small interval of times to get accurate and error free results of experiments.

1.12: What is meant by significant figures of a measurement? (GRW 2013)

Ans: In any measurement all the accurately known digits and first doubtful digit is known as significant figure.

1.13: How is precision related to the significant figures in a measured quantity?

Ans: An improvement in the quality of measurement by using better instrument increases the significant figures in the measured result. More significant figure means greater precision. E.g. measurement of vernier callipers would be more precise than a metre rule, therefore measurements taken by vernier callipers would have more significant figures than that taken by metre rule.

Unit 1: Physical Quantities and Measurement

Long Questions

Q.1 Define Science.

Ans: The knowledge gained through observations and experimentations is called science.

The word "Science" is derived from the Latin word Scientia, which means knowledge. Various aspects of material objects were studied under a single a subject called natural philosophy. But as the knowledge increased, it was divided into two main streams:

(i) **Physical sciences:** It deals with the study of non-living things.

(ii) **Biological sciences:** It is concerned with the study of living things.

Q.2 Define the branches of Physics.

Ans: There are different branches of physics that are given as under:

1) Mechanics

It is the study of motion of objects, its causes and effects.

2) Heat

It is the branch of physics that deals with the nature of heat, modes of transfer and effects of heat.

3) Sound

It is the branch of physics that deals with the physical aspects of sound waves, their production, properties and applications.

4) Light

It is the branch of physics that deals with the physical aspects of light, its properties, working and use of optical instruments.

5) Electricity and Magnetism

It is the study of the charges at rest and in motion, their effects and their relationship with magnetism.

6) Atomic Physics

It is study of the structure and properties of atoms.

7) Nuclear Physics

It deals with the properties and behavior of nuclei and the particles within the nuclei.

8) Plasma Physics

It is the study of production, properties of the ionic state of matter – the fourth state of matter.

9) Geophysics

It is the study of the internal structure of Earth.

Q.3 Describe the importance of Physics in our daily life.

Ans: <u>**Positive Aspects:**</u>

1) Electricity is used not only to get light and heat but also mechanical energy that drives fans and electric motors etc. This is possible due to knowledge of physics.

2) The means of transportation such as car and airplanes; domestic appliances such as air conditioners, refrigerators, washing machines and microwave ovens etc. are the gifts of knowledge of physics.

3) The mean of communication such as radio, T.V, telephone and computer are the result of applications of physics.

4) A mobile phone allows us to contact people anywhere in the world and to get latest worldwide information. We can take and save pictures, sent and receive messages of our friends. We can also receive radio transmission and can use it as a calculator as well. All this is possible due to knowledge of physics.

<u>**Negative Aspects:**</u>

The scientific inventions have also caused harms and destruction of serious nature. One of which is the environmental pollution and the other is the deadly weapons.

Q.4 Define physical quantities. Also describe its types.

Ans: **Physical quantities:**

All measurable quantities are called physical quantities. A physical quantity possesses at least two characteristics in common. One is its numerical magnitude and the other is the unit in which it is measured.

Physical quantities are divided into two types:

Base quantities: The quantities on the basis of which other quantities are expressed are known as base quantities. For example length, mass, time, electric current, temperature, intensity of light and amount of substance.

Derived quantities: The quantities that are expressed in terms of base quantities are called derived quantities. For example area, volume, speed, force, work etc.

Q.5 What is international system of units? Briefly discuss.

Ans: There is a need of some standard quantities for measuring/comparing unknown quantities. Once a standard is set for a quantity then it can be expressed in terms of that standard quantity. This standard quantity is called a unit.

With the development in the field of science and technology, the need for a commonly acceptable system of units was seriously felt all over the world particularly to exchange scientific and technical information. The eleventh General conference on weight and Measures held in the Paris in 1960 adopted a world-wide system of measurement called international systems of units commonly referred as SI.

Q.6 Differentiate between base and derived units.

Ans: **Base units:** The units that describe base quantities are called base units. Each base quantity has it SI unit.

Quantities		Units	
Name	**Symbol**	**Name**	**Symbol**
Length	l	Meter	m
Mass	m	Kilogram	kg
Time	t	Second	s
Electric current	I	Ampere	A
Intensity of light	L	Candela	cd
Temperature	T	Kelvin	K
Amount of a substance	n	Mole	mol

Derived units: The units use to measure derived quantities are called derived units. Derived units are defined in terms of base units and are obtained by multiplying or dividing one or more base units with each other. For example the unit of area $(\text{meter})^2$ and the unit of volume $(\text{meter})^3$.

Q.7 Define prefixes. Also give examples.

Ans: The words or letters added before a unit and stand for the multiples or sub-multiples of that unit are known as prefixes.

Examples: Kilo (10^3), Mega (10^6) micro (10^{-6}) nano (10^{-9}) etc.

Q.8 Define scientific notation. Also give examples.

Ans: In scientific notation a number is expressed as some power of ten multiplied by a number between 1 and 10.

For example: 62750 in scientific notation can be expressed as 6.275×10^4.

Distance of moon from earth is 384000000 metres. In scientific notation it can be expressed as 3.84×10^8 metres.

Q.9 Briefly describe a metre rule and measuring tape.

Ans: **Metre Rule:** A metre rule is a length measuring instrument. It is commonly used in the laboratories to measure length of an object or distance between two points.

Construction: It is one metre long which is equal to 100 centimetres. Each centimetre is divided into 10 small divisions called milimetre(mm). Thus one millimetre or 0.1 cm is the smallest reading that can be taken using a metre rule and is called its least count.

How can we avoid errors in the measurement?

While measuring length, or distance, eye must be kept vertically above the reading point. The reading becomes doubtful if the eye is positioned either left or right to the reading point.

Measuring Tape: Measuring tapes are used to measure length in metres and centimeters.

Construction:

A measuring tape consists of a thin and long strip of cotton, metal or plastic generally 10m, 20m, 50, or 100 m long. Measuring tapes are marked in centimetres as well as in inches.

Q.10 Write a detail note on vernier callipers.

Vernier Calipers is a device which is generally used to measure length as small as $\frac{1}{10}$th of a milimetre (0.1 mm).

Construction

A Vernier Calipers consist of two jaws One is the fixed with main scale attached to it. Main scale has centimetre and millimetre marks on it. The other jaw is a moveable jaw, It has vernier scale having 10 divisions over it such that each of its division is 0.9 mm.

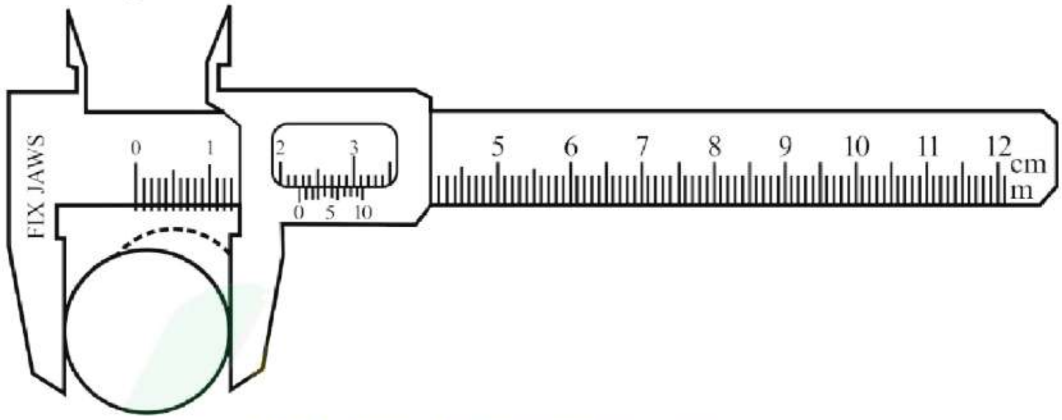


Figure 1.8: A cylinder placed between the outer jaws of Vernier Callipers.

Vernier constant: The difference between one small division on main scale and one vernier Scale division is called vernier constant or lest count of vernier calipers.

One small division on main scale $= 1$,

One small division on main scale $= 1$ 0.9 mm

$\therefore$ Least count $= 1\text{ mm} - 0.9\text{ mm}$

$= 0.1\text{ mm}$

Least count of vernier callipers can be also be found as follows

$$\text{Least count of verier callipers} = \frac{\text{smallest reading on main scale}}{\text{Total no. of divisions on vernier scale}}$$

$$= \frac{1\text{mm}}{10}$$

$$= 0.1\text{ mm}$$

$$= \frac{0.1}{10}$$

$$= 0.01\text{ cm}$$

Working of vernier callipers: First of all find the error in the measuring instrument known as zero error.

To find the zero error, close the jaws of vernier callipers gently. If the zero line of the vernier scale coincide with the zero of the main scale then the zero error is zero. (Nil)

Zero error will exist if zero line of the vernier scale is not coinciding with the zero of the mains scale. There are two types of errors.

Positive zero error: Zero error will be positive if zero line of vernier scale is on the right side of the zero of the main scale.

Negative zero error: Zero error will be negative if zero line of vernier scale is on the left side of the zero of the main scale.

Zero correction: Knowing the zero error, necessary correction can be made to find the correct measurement. Such a correction is called zero correction of the instrument. Zero correction is the negative of zero error.

Taking a reading on vernier callipers:

To find the diameter of a solid cylinder using a vernier callipers place the solid cylinder between jaws of the vernier callipers. Close the jaws till they press the opposite sides of the object gently. Note the complete division of the main scale before the vernier scale zero. Next find the vernier scale division that is coinciding with any division on the main scale. Multiply it by least count of vernier callipers and add it in the main scale reading. This will give the diameter of the solid cylinder. Add zero correction to get the correct measurement.

Q.11 Write a note on the Screw Gauge.

Ans: A screw gauge is an instrument used to measure small lengths accurately up to one-hundredth part of a millimeter. It is also called micrometer screw gauge. It accuracy is greater than a vernier calipers.

Construction

It consists of a U-shaped metal frame with a metal stud at one end. A hollow cylinder (or sleeve) has a millimeter scale over it along a line called index line parallel to its axis. The hollow cylinder acts as a nut. A thimble has a threaded spindle inside it.

Circular Scale

The thimble has 100 divisions around one end. It is circular scale of the screw gauge. As thimble completes one rotation, 100 divisions pass the index line and the thimble moves 1 mm along the main scale. Thus each division of circular scale crossing the index line moves the thimble through 1/100 mm or 0.01 mm on the main scale. Thus each division of circular scale crossing the index line moves the thimble through 1/100 mm or 0.01 mm.

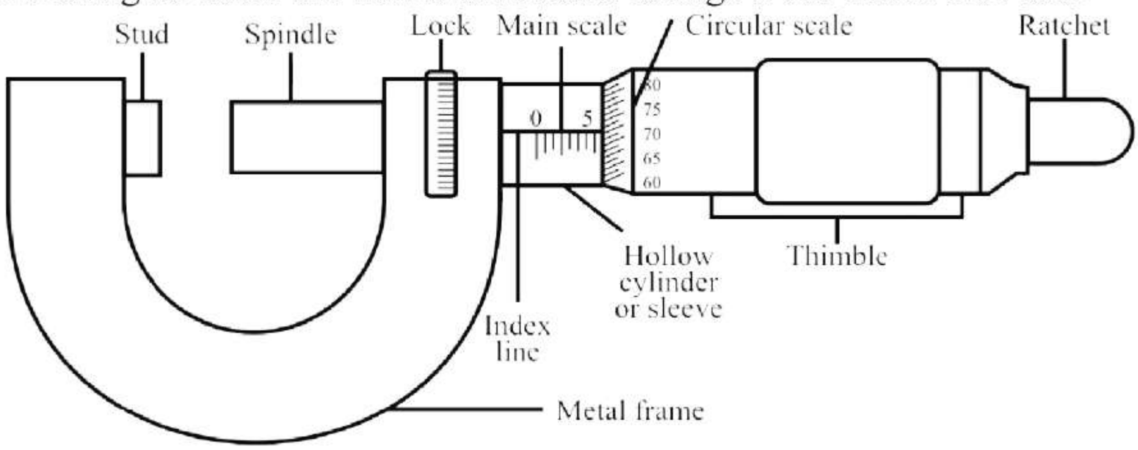


Figure 1.9: A micrometer screw gauge

Pitch

As the thimble completes one rotation, the spindle moves 1 mm along the index line. It is because the distance between consecutive threads on the spindle is 1 mm; the distance is called the pitch of screw gauge on the spindle.

Least count

Least count of a screw gauge can also be found as given below:

$$\text{Least count} = \frac{\text{pitch of screw gauge}}{\text{no. of divisions on circular scale}}$$

$$= \frac{1\,\text{mm}}{100}$$

$$= 0.01\ \text{mm} = 0.001\ \text{cm}$$

The least count of the screw gauge is 0.01 mm or 0.001 cm.

Working of a Screw Gauge

The first step is to find the zero error of the screw gauge. Close the gap between the spindle and the stud of the screw gauge by rotating the ratchet in clockwise direction. If zero of circular scale coincides with the index line, then zero error will be zero. If zero of circular scale does not coincide with index line, then there will be zero error in the screw gauge.

There are two types of zero errors:

(i) Positive Zero Error

(ii) Negative Zero Error

Positive Zero Error

Zero error will be positive if the zero of circular scale is behind the index line. In this case multiply the number of divisions on the circular scale that has not crossed the index line with the least count of the screw gauge to find positive zero error.

Negative Zero Error

Zero error will be negative if the zero of circular scale has crossed the index line. In this case multiply the number of divisions on the circular scale that has crossed the index line with the least count of the screw gauge to find negative zero error.

Taking reading on a screw gauge:

To find the diameter of a given wire place the given wire in the gap between stud and spindle of the screw gauge. Turn the ratchet so that the object is pressed gently between the stud and the spindle. Note main scale as well as circular scale readings to find the diameter of the given wire. Multiply circular scale reading with least count and add it in the main scale reading. This will give diameter of wire. Add zero correction to get the correct measurement.

Mass Measuring Instruments

Q.12 What is Physical Balance? And how it is used?

Ans: A common physical balance is a laboratory instrument that is used to measure the mass of various objects by comparison.

Construction

It consists of a beam resting at the center on a fulcrum as shown in the figure. The beam carries scale pans over the hooks on either side. Unknown mass is placed on the left pan. Find some suitable standard masses that cause the pointer to remain at zero on raising the beam.

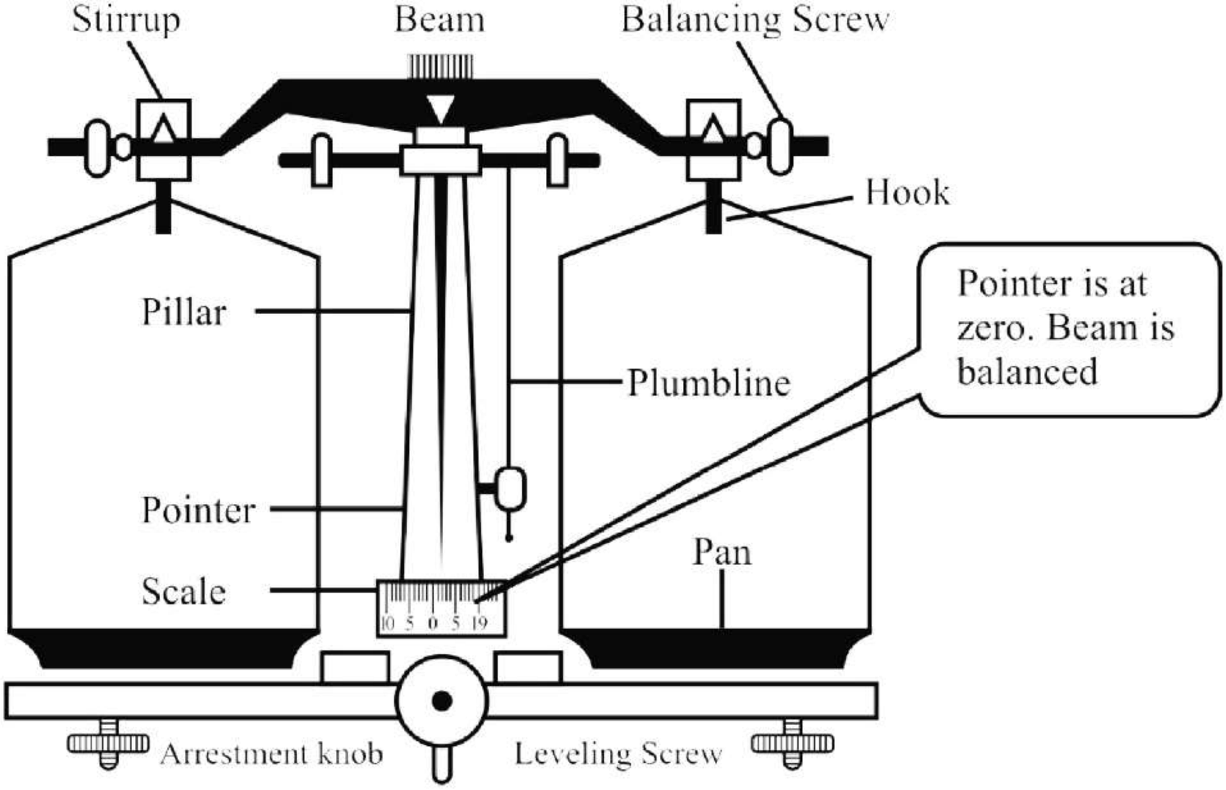


Figure 1.14: A physical balance

Example:

Find the mass of a small stone by a physical balance

Solution

Follow the following steps to measure the mass of a given object.

(i) Adjusting leveling screws with the help of plumb line to level the platform of physical balance.

(ii) Raise the beam gently by turning the arresting knob clockwise. Using balancing screws at the ends of its beam, bring the pointer at zero position.

(iii) Turn the arresting knob to bring the beam back on its support. Place the given object (stone) on its left pan.

(iv) Place suitable standard masses from the weight box on the right pan. Raise the beam. Lower the beam if its pointer is not at zero.

(v) Repeat adding or removing suitable standard masses in the right pan till the pointer rests at zero on raising the beam.

(vi) Note the standard masses on the right pan. Their sum is the mass of object on the left pan.

Q.13 Briefly explain lever balance and electronic balance?

Ans: Lever Balance:

A lever balance consists of a system of levers. When lever is lifted placing the object in one pan and standard masses on the other pan, the pointer of the lever system moves. The pointer is brought to zero by varying standard masses. The sum of these standard masses is the mass of object.

Electronic Balance:

Electronic balances come in various ranges; milligram ranges, gram ranges and kilogram ranges. Before measuring the mass of a body, it is switched ON and its reading is set to zero. Next place the object to be weighed. The reading on the balance gives you the mass of the body placed over it.

Q.14 Which one of the following is the most accurate?

Beam balance, Physical balance, and Electronic balance

Ans: The mass of one rupee coin is done using different balances as given below:

(a) Beam Balance

Mass of coin = 3.2 g

A sensitive beam balance may be able to measure mass accurately as small as 0.1 g or 100 mg. i.e. least count of beam balance is 0.1 g or 100 mg.

(b) Physical balance

Mass of the coin = 3.24 g

Least count of physical balance is 0.01 g or 10 mg. therefore, measurement taken by physical balance would be more precise than a sensitive beam balance.

(c) Electronic balance

Mass of coin = 3.247 g

Least count of electronic balance is 0.001 g or 1 mg. Therefore, its measurement would be more precise than a sensitive physical balance. The electronic balance is most sensitive balance than all the balances given above.

Q.15 Write a note on the Stop Watch.

Ans: "An instrument used to measure the time interval or specific period of an event is known as stop watch".

Types of stop watch

There are two types of stop watch.

(i) Mechanical stop watch

(ii) Digital stop watch (Electronic stop watch)

(i) Mechanical Stop Watch

A mechanical stop watch can measure a time interval up to a minimum 0.1 second.

How to use

A mechanical stop watch has a knob that is used to wind the spring that powers the watch. It can also be used as start – stop and reset button. The watch starts when the knob is pressed once. When pressed a second time, it stops the watch while the third time press brings the needle back to zero position.

Figure 1.17: A mechanical stopwatch

(ii) Electronic/Digital Stop Watch

Digital stop watch commonly used in laboratories can measure a time interval accurately up to 1/100 second or 0.01 second.

How to use

The digital stop watch starts to indicate the time lapsed as start/stop button is pressed. As soon as start/stop button is pressed again, it stops and indicates the time interval recorded by it between start and stop of an event. A reset button restores its initial zero setting.

Named as stop watch

This watch is named stopwatch because it can be started or stopped at will as required when the duration of the time is to be measured.

Q.16 What do you know about Measuring Cylinder? How volume of liquids is measured by using this cylinder?

Ans: A measuring cylinder is a cylindrical tube that is used to measure the volume of the liquid or powdered substance. It is also used find the volume of an irregular shaped solid insoluble in a liquid by displacement method.

Construction

It is made of transparent plastic or glass, which has a vertical scale in milliliter (ml) or cubic centimeter (cm^3). Measuring cylinders have different capacities from 100 mL to 2500 mL.

Measurement of Volume

When a liquid is put in measuring cylinder, the volume is noted on the scale in front of the meniscus of the liquid. The meniscus of most of the liquids curve downwards whiles the meniscus of mercury upwards.

Precautions

To measure correctly the volume of the liquid following precautions are kept in mind:

(i) The cylinder must be placed on horizontal surface.

(ii) The eye should be kept on a level with the bottom of the meniscus (curved surface). When the eye is above the liquid level, the meniscus appears higher on the scale. Similarly when the eye is below the liquid level, the meniscus appears lower than actual height of the liquid.

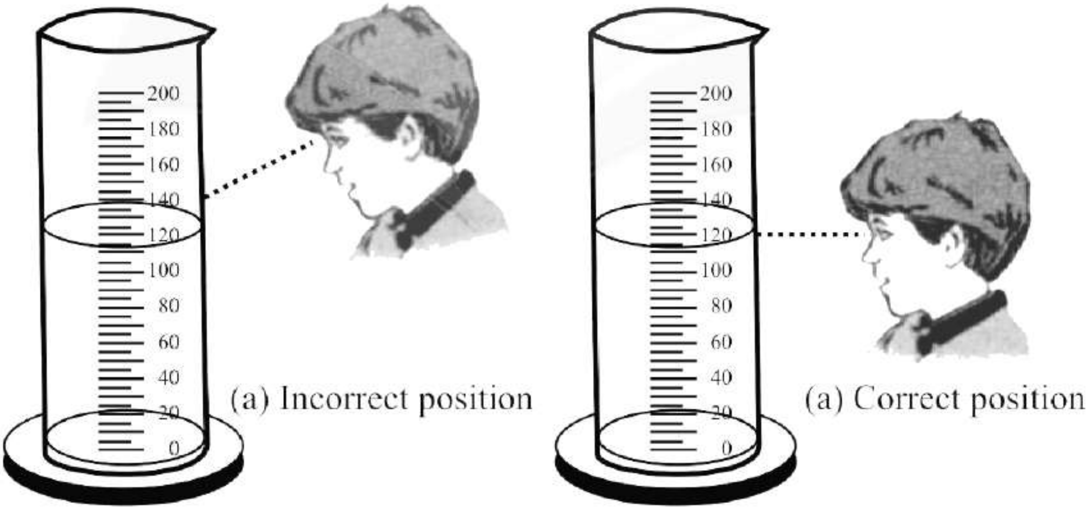


Figure 1.19 (a) Wrong way to note the liquid level keeping eye above liquid level. (b) correct position of eye to note the liquid level keeping eye at liquid level.

Measuring Volume of an irregular shaped solid:

Volume of irregular shaped solids is found by displacement method.

Displacement method

The solid is lowered into measuring cylinder containing water/liquid. The level of water/liquid rises. The increase in the volume of water/liquid is the volume of the given solid object.

Method

Let us find the volume of a small stone. Take the volume V_i of water in the cylinder. Tie the solid with a thread. Lower the solid into the cylinder till it is fully immersed in water. Note the volume V_f of water and the solid. Volume of the solid will be $V_f - V_i$.

Q.17 Define and explain Significant figures. What are the main points to be kept in mind while determining the significant figures of a measurement?

Ans: All the accurately known digits and the first doubtful digit in a measurement are called significant figures. It reflects the precision of a measured value of a physical quantity.

The accuracy in measuring a physical quantity depends upon various factors.

- The quality of the measuring instrument
- The skill of the observer
- The number of observations made

Example

A student measures the length of a book as 18 cm using a measuring tape. The numbers of significant figures in this measured value are two. The left digit 1 is the accurately known digit. While the digit 8 is the doubtful digit for which the student may not be sure.

Rules for determining Significant Figures

The following rules are helpful in identifying significant figures:

(i) Non-zero digits are always significant. For example 27 has 2 significant digits.

(ii) Zeros in between two significant figures are also significant. For example in 1.406, the number of significant figures is 4.

(iii) In any observation, the zeros on the left side of the decimal point for the purpose of spacing the decimal point are not significant. For example in 0.0036, the number of significant figures is 2.

(iv) Final or ending zeros on the right side in the decimal fractions are considered significant. For example the number of significant figures in 2.450 is four.

(v) In whole numbers that end in one or more zeros without a decimal point. These zeros may or may not be significant. In such cases, it is not clear which zeros serves to locate the position value and which are actually parts of the measurement. In such a case, express the quantity using scientific notation to find the significant zero.

(vi) If numbers are recorded in scientific notation then all the digits before the power of 10 are significant. For example in 1.40×10^5, the number of significant figure is three.

Q.18 Write down the rules to round off the numbers?

The following rules are used to round off the numbers:

(i) If the last digit is less than 5 then it is simply dropped. This decreases the number of significant digits in the figure.

Example

1.943 is rounder to 1.94 (3 significant figures)

(ii) If the last digit is greater than 5, then the digit on its left is increased by one. This also decreases the number of significant digits in the figure.

Example

1.47 is rounded to two significant digits 1.5

(iii) If the last digit is 5, then it is rounded to get nearest even number.

Example

1.35 is rounded to 1.4

1.45 is rounded to 1.4

Unit 1: Physical Quantities and Measurement

Multiple Choice Questions

1. **The branch of science which deals with the study of properties of matter, energy and their mutual relationship is called:**
   (a) Astronomy **(b)** Physics
   (c) Geology **(d)** Chemistry
2. **The study of properties of the ionic state of matter is called**
   (a) Plasma Physics **(b)** Astrophysics
   (c) Sound **(d)** Electromagnetism
3. **The study of internal structure of earth and its activities like seismography is called:** **(GRW 2013, 2015)**
   (a) Solid state physics **(b)** Heat
   (c) Mechanics **(d)** Geophysics
4. **The study of the isolated nuclei of an atom is called:**
   (a) Plasma Physics **(b)** Astrophysics
   (c) Nuclear Physics **(d)** Biophysics
5. **Much of the universe is made up of:**
   (a) Solid **(b)** Liquid
   (c) Plasma **(d)** All of above
6. **The international system of units is abbreviated as:**
   (a) IS **(b)** SI
   (c) Both a & b **(d)** none
7. **The terms used internationally for multiples and submultiples of various units are known as:**
   (a) Standard **(b)** Scientific notation
   (c) Prefixes **(d)** All of above
8. **Meter rule can measure the length accurately up to:**
   (a) 1 mm **(b)** 1 cm
   (c) 1 m **(d)** 1 km
9. **------------- can accurately measure up to one tenth of a millimeter.**
   (a) Meter rule **(b)** Vernier callipers
   (c) Screw Gauge **(d)** All
10. **The SI unit of intensity of light is:**
    (a) Newton **(b)** Kelvin
    (c) Kilogram **(d)** Candela
11. **One meter is equal to:**
    (a) 10^3 mm **(b)** 10^{-3} km
    (c) 10^2 cm **(d)** All

12. Volume measuring scale has a vertical scale in:

(a) Milliliter | **(b)** cm^3

(c) Both a & b | **(d)** none

13. One Femto is equal to:

(a) 10^{15} | **(b)** 10^{-15}

(c) 10^{-9} | **(d)** 10^{-12}

14. The least count of vernier calipers is: **(LHR 2015)**

(a) 0.1cm | **(b)** 0.1mm

(c) 0.01cm | **(d)** Both b & c

15. Total length of the vernier scale is:

(a) 1mm | **(b)** 9 mm

(c) 10 mm | **(d)** 1 cm

16. Number of divisions on the vernier scale are:

(a) 1 | **(b)** 9

(c) 10 | **(d)** 100

17. Length of the smallest division on main scale of the vernier calipers is:

(a) 1 cm | **(b)** 1 mm

(c) 0.9 mm | **(d)** All

18. Separation between division on the vernier scale of the vernier calipers is:

(a) 1 cm | **(b)** 1 mm

(c) 0.9 mm | **(d)** All

19. If zero of the vernier scale is on the right side of the zero of the main scale then it is known as ------------ zero error:

(a) Positive | **(b)** Negative

(c) No error | **(d)** none of these

20. If zero of the vernier scale is on the left side of the zero of the main scale then it is known as ------------ zero error:

(a) Positive | **(b)** Negative

(c) None of these | **(d)** No error

21. If zero of the vernier scale is on the right side of the zero of the main scale then zero error is to be:

(a) Added | **(b)** Subtracted

(c) Multiplied | **(d)** Divided

22. If zero of the vernier scale is on the left side of the zero of the main scale then zero error is to be:

(a) Added | **(b)** Subtracted

(c) Multiplied | **(d)** Divided

23. The least count of Screw Gauge is:

(a) 0.1 mm | **(b)** 0.01 mm

(c) 0.1 cm | **(d)** 0.01 cm

24. Total number of divisions on the circular scale of Screw Gauge are:

(a) 10 | **(b)** 20

(c) 100 | **(d)** 200

25. Pitch of the screw gauge is:

(a) 1m | **(b)** 1 mm

(c) 1 cm **(d)** 0.1 mm

26. **If the zero of the circular scale is above the horizontal line then the zero error will be:**
(a) Positive **(b)** Negative
(c) None of these **(d)** No error

27. **If the zero of the circular scale is below the horizontal line then the zero error will be:**
(a) Positive **(b)** Negative
(c) None of these **(d)** No error

28. **If the zero of the circular scale is above the horizontal line then the zero error is to be:**
(a) Added **(b)** Subtracted
(c) Multiplied **(d)** Divided

29. **If the zero of the circular scale is below the horizontal line then the zero error is to be:**
(a) Added **(b)** Subtracted
(c) Multiplied **(d)** Divided

30. **For scientific notation internationally accepted practice is that there should be ------- digit(s) before the decimal point.**
(a) One **(b)** Two
(c) Three **(d)** No

31. **In screw gauge, the distance moved forward or backward in one complete rotation of the circular scale is known as:**
(a) Least count **(b)** Pitch
(c) Constant **(d)** None of above

32. **A physical balance is used to measure:**
(a) Weight **(b)** Volume
(c) Length **(d)** mass

33. **Least count of mechanical stop watch is:**
(a) 1 second **(b)** 1 minute
(c) 0.1 second **(d)** 0.01 second

34. **Least count of digital stop watch is:**
(a) 1 second **(b)** 1 minute
(c) 0.1 second **(d)** 0.01 second

35. **In any measurement, the accurately known digits and first doubtful digit are known as:**
(a) Prefixes **(b)** Significant figures
(c) Real numbers **(d)** All

36. **The radius of wire is 0.022 cm. The number of significant figures in the measurements are:**
(a) 1 **(b)** 2
(c) 3 **(d)** 4

37. **The number of significant figures in 1.406 are:**
(a) 4 **(b)** 3
(c) 2 **(d)** 1

38. **The number of significant figures in 1.40×10^5 are:**
(a) 1 **(b)** 2
(c) 3 **(d)** 4

39. **Vernier constant is also known as ----------- of vernier calipers:**
(a) Pitch **(b)** Proportionality constant

(c) Vernier value **(d)** least count

40. **The zeros in between the digits are considered:**

(a) Significant **(b)** Insignificant

(c) Constant **(d)** None of above

41. **10^6 Stands for:**

(a) Micro **(b)** Pico

(c) Nino **(d)** Mega

42. **1μs is equal to:**

(a) 10^{-9} s **(b)** 10^{-3} s

(c) 10^{-6} s **(d)** 10^{-12} s

43. **To measure correctly the volume of the liquid, the eye must be kept on the ----------- surface of meniscus:**

(a) Lower **(b)** Upper

(c) Middle **(d)** All of above

44. **SI unit of electric charge is**

(a) Ampere **(b)** Kelvin

(c) Pascal **(d)** Coulomb

45. **The word science is derived from the Latin word**

(a) Scientia **(b)** Santia

(c) Scient **(d)** None of these

46. **Least count of digital vernier callipers is**

(a) 0.1mm **(b)** 0.01 mm

(c) 0.001 mm **(d)** 1 mm

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	b	11	d	21	b	31	b	41	d
2	a	12	c	22	a	32	d	42	c
3	d	13	b	23	b	33	c	43	a
4	c	14	d	24	c	34	d	44	d
5	c	15	b	25	b	35	b	45	a
6	b	16	c	26	b	36	b	46	b
7	c	17	b	27	a	37	a		
8	a	18	c	28	a	38	c		
9	b	19	a	29	b	39	d		
10	d	20	b	30	a	40	a		

Unit 1: Physical Quantities and Measurement

Problems

1.1: Express the following quantities using prefixes.
(a) 5000 g
(b) 2000 000 W
(c) 52 x 10^{-10} kg
(d) 225 x 10^{-8} s

Ans:

(a) 5000 g = 5 x 10^3 g = 5kg
(b) 2000 000 W = 2 x 10^6 W = 2 MW
(c) 52 x 10^{-10} kg = 5.2 x 10^1 x 10^{-10} x 10^3 g = 5.2 x 10^{-6} g = 5.2 μ g
(d) 225 x 10^{-8} s = 2.25 x 10^2 x 10^{-8} s = 2.25 x 10^{-6} s = 2.25 μ s

1.2: How do the prefixes micro, nano and pico relate to each other?

Ans: **<u>Relation between micro and nano:</u>**

$$1 \text{ nano} = 10^{-9}$$
$$= 10^{-3} \times 10^{-6}$$
$$\boxed{1\text{nano} = 10^{-3}\text{ micro}}$$

<u>Relation between micro and pico</u>

$$1 \text{ pico} = 10^{-12}$$
$$= 10^{-6} \times 10^{-6}$$
$$\boxed{1\text{pico} = 10^{-6}\text{ micro}}$$

<u>Relation between nano and pico</u>

$$1 \text{ pico} = 10^{-12}$$
$$= 10^{-3} \times 10^{-9}$$
$$\boxed{1\text{pico} = 10^{-3}\text{ nano}}$$

1.3: Your hairs grow at the rate of 1mm per day. Find their growth rate in mms^{-1}.
(LHR 2013, GUJ 2015)

Ans: Growth rate = 1 mm per day

$$= \frac{1\,\text{mm}}{1\,\text{day}}$$

$$= \frac{1 \times 10^{-3}\,\text{m}}{8.64 \times 10^4\,\text{s}}$$

$$= \frac{1}{8.64} \times 10^{-3} \times 10^{-4}\ ms^{-1}$$
$$= 0.1157 \times 10^{-7}\ ms^{-1}$$
$$= 11.57 \times 10^{-2} \times 10^{-7}\ ms^{-1}$$
$$= 11.57 \times 10^{-9}\ ms^{-1} = 11.57\ nms^{-1}$$

1.4: Rewrite the following in standard form.

(a) 1168 x 10^{-27}

(b) 32 x 10^{5}

(c) 725 x 10^{-5} kg

(d) 0.02 x 10^{-8}

Ans:

(a) $1168 \times 10^{-27} = 1.168 \times 10^{3} \times 10^{-27} = 1.168 \times 10^{-24}$

(b) $32 \times 10^{5} = 3.2 \times 10^{1} \times 10^{5} = 3.2 \times 10^{6}$

(c) 725×10^{-5} kg $= 7.25 \times 10^{2} \times 10^{-5} \times 10^{3}$ g $= 7.25$ g

(d) $0.02 \times 10^{-8} = 2.0 \times 10^{-2} \times 10^{-8} = 2.0 \times 10^{-10}$

1.5: Write the following quantities in standard form.

(a) 6400 km

(b) 380 000 km

(c) 300 000 000 ms^{-1}

(d) seconds in a day

Ans:

(a) 6400 km $= 6.4 \times 10^{3}$ km

(b) 38000 km $= 3.8 \times 10^{5}$ km

(c) 300 000 000 $ms^{-1} = 3.0 \times 10^{8}\ ms^{-1}$

(d) 1 day = 24 hours = 24 x 3600 s = 86400 s $= 8.64 \times 10^{4}$ s

1.6: On closing the jaws of a vernier callipers, zero of the Vernier scale is on the right of it main scale such that 4th division of its vernier scale coincides with one of the main scale division. Find its zero error and zero correction.

Ans: Number of division of Vernier scale = 4

Least count of Vernier calipers = 0.01 cm

Zero error = 4 x 0.01 cm = 0.04 cm

As zero of the Vernier scale is at the right side of the zero of the main scale so zero error will be positive.

So Zero correction = - 0.04 cm

1.7: A screw gauge has 50 divisions on its circular scale. The pitch of the screw gauge is 0.5 mm. What is its least count? (LHR 2013)

Ans: No. of divisions on circular scale = 50

Pitch = 0.5 mm

$$\text{As least count} = \frac{\text{pitch of screwguage}}{\text{Number of circular scale divisions}}$$

$$\text{Least Count} = \frac{0.5\text{mm}}{50} = 0.01\text{ mm} = 0.001\text{ cm}$$

1.8: Which of the following quantities have three significant figures? (LHR 2015, GRW 2015)

(a) 3.0066 m

(b) 0.00309 kg

(c) 5.05 x 10^{-27} kg

(d) 2001 s

Ans: b and c

1.9: What are the significant figures in the following measurements? (LHR 2015, GRW 2015)

	(a) 1.009 m	**(b) 0.00450 kg**	**(c) 1.66 x 10^{-27} kg**	**(d) 2001 s**
Ans:	(a) 4	(b) 3	(c) 3	(d) 4

1.10: A chocolate wrapper is 6.7 cm long and 5.4 cm wide. Calculate its area up to reasonable number of significant figures. (GRW 2013, LHR 2014)

Ans: Given data:

Length of chocolate wrapper = l = 6.7 cm

Width of chocolate wrapper = w = 5.4 cm

Required:

Area of chocolate wrapper = A =?

Solution:

As we know that

Area =length x width

By putting the values we have

Area = 6.7 cm x 5.4 cm

= 36.18 cm^2

Result:

As the least number of significant figures in observed measurements are 2

So Area = 36 cm^2

Unit 2: Kinematics

Textbook Exercise Questions

2.1 Encircle the correct answer from the given choices.

i. A body has translatory motion if it moves along a:

(a) Straight line **(b)** circle

(c) line without rotation ✓ **(d)** Curved path

ii. The motion of a body around an axis is called __________ motion. (LHR 2015)

(a) Circular **(b) Rotatory ✓**

(c) Vibratory **(d)** Random

iii. Which of the following is a vector quantity?

(a) Speed **(b)** distance

(c) Displacement ✓ **(d)** power

iv. If an object is moving with constant speed then its distance-time graph will be a straight line.

(a) Along time-axis **(b)** Along distance-axis

(c) Parallel to time-axis **(d) Inclined to time-axis ✓**

v. A straight line parallel to time-axis on a distance-time graph tells that the object is:

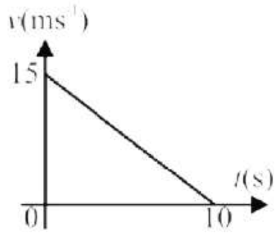
(a) Moving with constant speed **(b) At rest ✓**

(c) Moving with variable speed **(d)** In motion

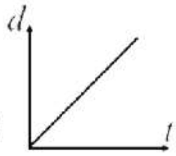
vi. The speed-time graph of a car is shown in the figure, which of the following statement is true?

(a) Car has an acceleration of 1.5 ms^{-2} **(b)** Car has constant speed of 7.5ms^{-1}

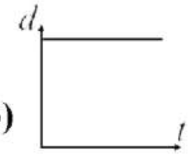
(c) Distance travelled by the car is 75 m ✓ **(d)** Average speed of the car is 15 ms^{-1}

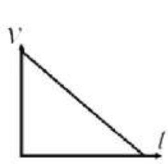


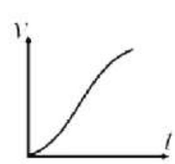
vii. Which of the following graphs is representing uniform acceleration? (LHR 2015)

(a) 

✓

(b) 

(c) 

(d) 

viii. **By dividing displacement of a moving body with time, we obtain:**

(a) Speed | **(b)** Acceleration
(c) Velocity ✓ | **(d)** Deceleration

ix. **A ball is thrown vertically upward. It velocity at the highest point is:**

(a) -10 ms^{-2} | **(b) Zero✓**
(c) 10 ms^{-2} | **(d)** None of these

x. **A change in position is called:** **(GRW 2015)**

(a) Speed | **(b)** Velocity
(c) Displacement✓ | **(d)** Distance

xi. **A train is moving at a speed of 36kmh^{-1}. Its speed expressed in ms^{-1} is: (GRW 2015)**

(a) 10 ms^{-1}✓ | **(b)** 20 ms^{-1}
(c) 25 ms^{-1} | **(d)** 30 ms^{-1}

xii. **A car starts from rest. It acquires a speed of 25 ms^{-1} after 20 s. the distance moved by the car during this time is:**

(a) 31. 25 m | **(b) 250 m✓**
(c) 500 m | **(d)** 5000 m

2.2 Explain translatory motion and give examples of various types of translatory motion.

Ans: Such type of motion in which a body moves along a line without any rotation. The line may be straight or curved.

(i) Linear motion

- The motion of freely falling bodies
- A car moving along the straight line

(ii) Circular motion

- A stone attached with thread, when whirled, it will move along a circular path.
- A toy train moving on a circular track.

(iii) Random motion

- The flight of an insect and birds
- Motion of dust or smoke particles in air

2.3 Differentiate between the following:

(i) Rest and motion
(ii) Circular motion and rotatory motion
(iii) Distance and displacement **(GRW 2014)**
(iv) Speed and velocity **(LHR 2013, 2015)**
(v) Scalars and vectors **(GRW 2013, LHR 2014, 2015)**

(i) Difference between Rest and Motion

REST	MOTION
If a body does not change its position with respect to surroundings then it is said to be in a state of rest.	If a body continuously changes its position with respect to surroundings then it is said to be in a state of motion.

(ii) Circular motion and rotatory motion.

CIRCULAR MOTION	ROTATORY MOTION
The motion of an object in a circular path is known as circular motion. **Examples:** • The motion of earth around the sun. • The motion of electron around nucleus.	The spinning motion of a body about its axis is called rotatory motion. **Examples:** • The motion of wheel about its axis. • Motion of ceiling fan.

(iii) Difference between Distance and Displacement.

DISTANCE	DISPLACEMENT
• Actual (total) length between two points is known as distance. • It is a scalar quantity. • It is represented by "S".	• The shortest distance between two points is known as displacement. • It is a vector quantity. • It is represented by "$\vec{d}$".

(iv) Difference between Speed and Velocity

SPEED	VELOCITY
• The distance covered in unit time is known as speed. • Mathematically speed is given by Speed = distance/time $v = \frac{S}{t}$ • It is a scalar quantity.	• The rate of displacement of a body is called velocity. • Mathematically velocity is given by Velocity = displacement/time $\vec{v} = \frac{\vec{d}}{t}$ • It is a vector quantity.

(v) Difference between scalar and vector.

SCALAR	VECTOR
Physical quantities which are completely described by their magnitude only are known as scalars. **Example** Speed, distance, time etc.	Physical quantities which are completely described by their magnitude and direction as well are known as vectors. **Example** Force, displacement, velocity etc.

2.4 Define the terms speed, velocity, and acceleration. **(GRW 2013, LHR 2015)**

Ans: **<u>Speed</u>**

The distance covered by an object in unit time is called its speed.

Mathematical Formula

$$\text{Speed} = \frac{\text{Distance covered}}{\text{Total time}}$$

$$v = \frac{S}{t}$$

Distance = speed x time

Or $S = v \times t$

Velocity

The rate of displacement of a body is called velocity.

Mathematical form

$$\text{velocity} = \frac{\text{displacement}}{\text{time taken}}$$

$$\vec{v} = \frac{\vec{d}}{t}$$

Here $\vec{d}$ is the displacement of the body moving with velocity $\vec{v}$ in time t.

Acceleration

The rate of change of velocity of a body is known as acceleration.

Mathematical form

If a body is moving with initial velocity 'v_i' and after some time 't' its velocity becomes 'v_f' then change in velocity will occur in time t.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{total time}}$$

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{total time}}$$

So $$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

2.5 Can a body moving at a constant speed have acceleration? (LHR 2014)

Ans: A body moving with constant speed can have acceleration if its direction of motion changes continuously. For example a body moving with constant speed in a circular path has an acceleration.

2.6 How do riders in a Ferris wheel possess translatory motion but not circular motion?

Ans: Riders in a Ferris wheel move in a circle without rotation therefore motion of rider in Ferris wheel is translatory not rotatory.

2.7 Sketch a distance – time graph for a body starting from rest. How will you determine the speed of a body from this graph?

Ans: The distance-time graph is shown below

The slope of the graph gives speed with the help of the formula

Speed (v) of the object = slope of line AB

$$= \frac{\text{distance EF}}{\text{time CD}}$$

$$= \frac{20\text{m}}{10\text{s}}$$

$$= 2\ \text{ms}^{-1}$$

The speed found from the graph is 2 ms^{-1}

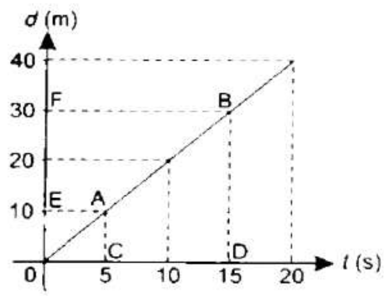


Figure 2.19: Distance-time graph showing constant speed.

2.8 What would be the shape of speed – time graph of a body moving with variable speed? (LHR 2013, 2014, 2015)

Ans: Lines OA and OB shows that body is moving with variable speed. Line OA shows that speed of body changes equally in equal intervals of time. Line OB shows that speed of body changes unequally in a equal intervals of time.

2.9 Which of the following can be obtained from speed – time graph of a body?

Ans: All the given quantities can be obtained form speed-time graph.

2.10 How can vector quantities be represented graphically? (LHR 2014, GRW 2014)

Ans: To represent a vector quantity graphically we draw a line known as represented line. The length of the line drawn is according to some selected scale give the magnitude of vector and an arrow on one end of this line shows the direction of vector.

2.11 Why vector quantities cannot be added and subtracted like scalar quantities?

Ans: Scalar quantities can be described completely by magnitude only and can be added or subtracted by simple arithmetic rules. Vector quantities in addition to magnitude also need direction for their description. So vectors cannot be added or subtracted by arithmetic rules due to direction.

2.12 How are vector quantities important to us in our daily life?

Ans: In order to locate a place from a reference point, we will have to describe the distance and direction of that place from reference point. Description of distance along with direction will make up a vector quantity. Hence by using vector quantities we can describe the position (or location) of bodies.

2.13 Derive equations of motion for uniformly accelerated rectilinear motion.

Ans: See Q.no.4 Long Question

2.14 Sketch a velocity – time graph for the motion of the body. From the graph explaining each step, calculate total distance covered by the body.

Ans: Total distance travelled

= area under the graph (trapezium OABC)

$= \frac{1}{2}$ (sum of parallel sides) x height

$= \frac{1}{2}$ (18s + 30 s) x (16 ms^{-1})

= 384 m

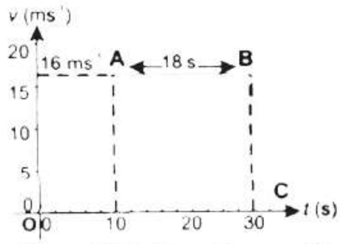


Figure 2.25: Speed-time graph of a car during 30 seconds.

Unit 2: Kinematics

Long Questions

Q.1 Define Translatory motion and its types. (LHR 2011, 2012, 2013 GRW 2013, 2015)

Ans: Such type of motion in which a body moves along a line without any rotation. The line may be straight or curved.

Examples

- Motion of a car in straight line
- Motion of electron around the nucleus
- Motion of gas molecules
- Aeroplane moving straight is in translational motion

Types of Translatory Motion

There are three types of translatory motion.

(i) Linear motion **(LHR 2014)**

(ii) Circular motion

(iii)Random motion **(LHR 2013, 2014)**

(i) Linear motion

If the motion of a body is in straight line, it is known as linear motion.

Examples

- The motion of freely falling bodies
- A car moving along the straight line

(ii) Circular motion

If a body moves in a circle then its motion is known as circular motion.

Examples

- A stone attached with thread, when whirled, it will move along a circular path.
- A toy train moving on a circular track.
- A bicycle or car moving along a circular track
- Earth moving around the sun in solar system

(iii) Random motion

The disordered or irregular motion of an object is called random motion.

Examples

- The flight of an insect and birds
- Brownian motion of gas or liquid molecules
- Motion of dust or smoke particles in air

Q.2 Explain Distance – time Graph.

Ans: The term distance and displacement are used interchangeably when the motion is in straight line. Similarly, if the motion is in a straight line then speed and velocity are also used interchangeably.

In distance – time graph, time is taken along horizontal axis while the vertical axis shows the distance covered by the object.

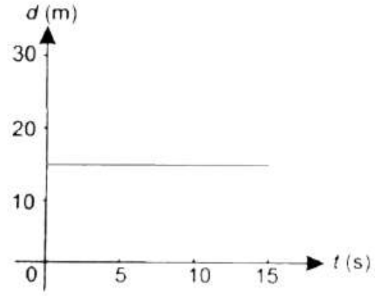


Figure 2.18: Distance-time graph when the object is at rest.

Object at Rest

In the graph shown in figure, the distance moved by the object with time is zero. That is the object is at rest. Thus a horizontal line parallel to time axis on a distance – time graph shows that speed of the object is zero.

Object moving with Constant Speed

The speed of an object is said to be constant if it covers equal distances in equal intervals of time. The distance – time graph as shown in figure is a straight line. Its slope gives the speed of the object.

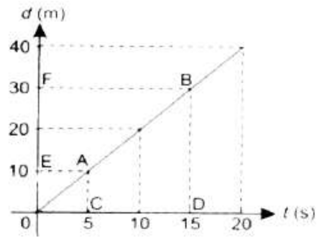


Figure 2.19: Distance-time graph showing constant speed.

Object moving with variable speed

When an object does not cover equal distances in equal intervals of time then its speed is not constant. In this case the distance – time graph is not a straight line as shown in figure. The slope of the curve at any point can be found from the slope of the tangent at that point.

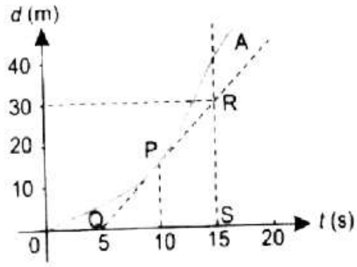


Figure 2.20: Distance-time graph showing variable speed.

Q.3 Explain Speed – Time Graph.

Ans: In a speed – time graph, time is taken along x – axis and speed is taken along y–axis.

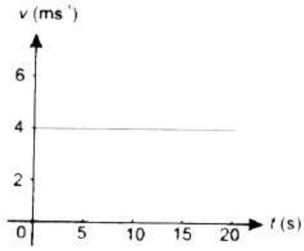


Figure 2.22: Speed-time graph showing constant speed.

Object moving with constant speed

When speed of an object is constant with time, then the speed – time graph will be a horizontal line parallel to time – axis as shown in figure. In other words, a straight line parallel to time axis represents constant speed of the object.

Object moving with uniformly changing speed (uniform acceleration)

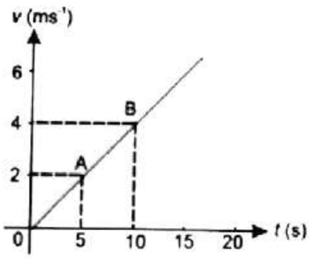


Figure 2.23: Graph of an object moving with uniform acceleration.

Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate. Thus its speed-time graph would be a straight line as shown in figure. A straight line means that the object is moving with uniform acceleration. Slope of the line gives the magnitude of its acceleration.

Distance travelled by a moving object

The area under a speed – time graph represents the distance travelled by the object. If the motion is uniform then the area can be calculated using appropriate formula for geometrical shapes represented by the graph.

Q.4 Derive first equation of motion using speed time graph. **(GRW 2013)**

- **Ans: Proof:**

Suppose a body is moving with initial velocity v_i in a straight line with uniform acceleration a. Its velocity becomes v_f after time t. The motion of the body is described by speed – time graph as shown in figure.

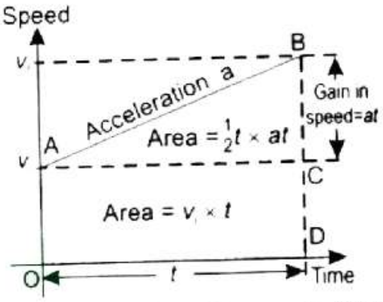


Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

$$\text{Slope of line AB} = \frac{BC}{AC}$$

We know that slope of line in speed-time graph gives the magnitude of acceleration.

$$\therefore \text{ Acceleration} = \frac{BC}{AC}$$

$$a = \frac{BC}{AC}$$

As AC = OD and BC = BD – CD

So, $$a = \frac{BD - CD}{OD}$$

As $BD = v_f$, $CD = v_i$ and $OD = t$

Hence $$a = \frac{v_f - v_i}{t}$$

Or $$v_f - v_i = at$$

Therefore, $$v_f = v_i + at$$

Which is required first equation of motion.

Q.5 Derive second equation of motion using speed-time graph. (LHR 2012, 2013)

Ans: Proof:

Suppose a body is moving with initial velocity v_i in a straight line with uniform acceleration a. Its velocity becomes v_f after time t. The motion of the body is described by speed – time graph as shown in figure.

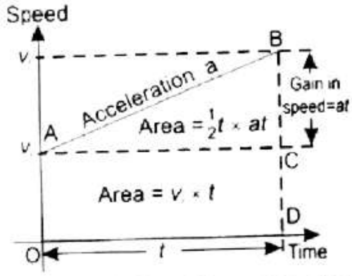


Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

In speed – time graph the total distance s travelled by the body is equal to the total area of trapezium OABD under the graph. i.e.

Area of the rectangle OACD $= OA \times OD$

$$= v_i \times t$$

Area of the triangle ABC $= \frac{1}{2}(AC \times BC)$

$$= \frac{1}{2}(OD \times BC)$$

$$= \frac{1}{2}\, t \times at$$

$$= \frac{1}{2} a t^2$$

Area of trapezium OABD = area of rectangle OACD + area of triangle ABC

Putting the values in the above equation, we get

$$s = v_i t + \frac{1}{2} at^2$$

which is required second equation of motion.

Q.6 Derive third equation of motion using speed-time graph. (GRW 2015)

Ans: Proof:

Suppose a body is moving with initial velocity v_i in a straight line with uniform acceleration a. Its velocity becomes v_f after time t. The motion of the body is described by speed – time graph as shown in figure.

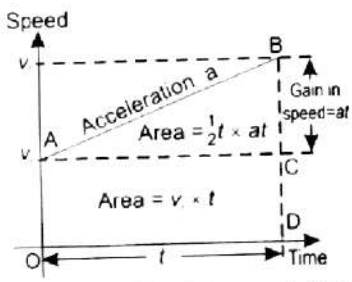


Figure 2.26: Speed-time graph. Area under the graph gives the distance covered by the body.

In speed – time graph the total distance s travelled by the body is equal to the total area of trapezium OABD under the graph.

$$\text{Area of trapezium OABD} = \frac{1}{2}[\text{sum of parallel sides}][\text{Perpendicular distance between parallel sides}]$$

$$s = \frac{1}{2}(BD + OA)(OD)$$

Or $\qquad 2S = (BD + OA)(OD)$

Multiply both sides by $\frac{BC}{OD}$, we get $\qquad$ (as $\frac{BC}{OD} = a$)

$$2\left(\frac{BC}{OD}\right)S = (BD + OA)(OD)\left(\frac{BC}{OD}\right)$$

$$2\left(\frac{BC}{OD}\right)S = (BD + OA)(BC)$$

$$2\left(\frac{BC}{OD}\right)S = (BD + OA)(BD - CD)$$

As $\qquad OA = CD = Vi$

$\frac{BC}{OD} = a,$

and $\qquad BD = v_f$

Putting the values in the in the above equation, we have

$$2\,aS = (v_f + v_i)(v_f - v_i)$$

$$2aS = v_f^2 - v_i^2$$

Which is required third equation of motion.

Unit 2: Kinematics

Multiple Choice Questions

1. **Study of motion of the bodies is known as:**
   (a) Heat **(b)** Light
   (c) Atomic physics **(d)** Mechanics
2. **Study of motion without discussing the cause of motion is called:**
   (a) Kinematics **(b)** Dynamics
   (c) Heat **(d)** Motion
3. **If a body does not change its position with respect to some observer then it will be in a state of:**
   (a) Rest **(b)** Motion
   (c) Uniform motion **(d)** Relative motion
4. **If a body changes its position with respect to some observer then it will be in state of:**
   (a) Rest **(b)** Motion
   (c) Uniform motion **(d)** Relative motion
5. **Rest and motion are ------------- states:**
   (a) Absolute **(b)** Constant
   (c) Variable **(d)** Relative
6. **Which one of the following is a vector quantity?**
   (a) Displacement **(b)** Speed
   (c) Volume **(d)** Work
7. **The spinning motion of a body about its axis is known as. (LHR 2015)**
   (a) Translatory motion **(b)** Vibratory motion
   (c) Rotatory motion **(d)** none of these
8. **When a body moves to and fro about a point and repeats its motion again and again about the same point then this motion is known as: (GRW 2014, 2015)**
   (a) Translatory **(b)** Vibratory
   (c) Rotatory **(d)** none of these
9. **The motion of the string of a violin is:**
   (a) Translatory **(b)** Vibratory
   (c) Rotatory **(d)** none of these
10. **Total length of a path between two points is known as:**
    (a) Velocity **(b)** Acceleration
    (c) Speed **(d)** Distance
11. **The shortest distance between two points is known as:**
    (a) Velocity **(b)** Displacement
    (c) Speed **(d)** Distance
12. **The area uner a speed time graph respresents**
    (a) Speed **(b)** Volume
    (c) Acceleration **(d)** Distance
13. **SI unit of speed is:**
    (a) ms^{-1} **(b)** mh^{-1}
    (c) kms^{-1} **(d)** All of these

14. **Speed is a ------------ quantity:**
(a) Vector (b) Scalar
(c) Both (d) none of these

15. **If a body covers equal distance in equal intervals of time, however small the intervals may be, then the speed of the body is known as:**
(a) Uniform (b) Variable
(c) Non uniform (d) All of these

16. **The rate of displacement with respect to time is known as:**
(a) Distance (b) Speed
(c) Velocity (d) Acceleration

17. **If the speed and direction of the moving body does not change with time then its velocity is said to be:**
(a) Uniform (b) Variable
(c) Constant (d) All of these

18. **If the speed or direction of the moving body changes with time then its velocity is said to be:**
(a) Uniform (b) Variable
(c) Constant (d) All of these

19. **Rate of change of velocity is known as:**
(a) Distance (b) Speed
(c) Velocity (d) Acceleration

20. **If the velocity of the body is increasing then its acceleration will be:**
(a) Positive (b) Negative
(c) Uniform (d) Variable

21. **If the velocity of the body is decreasing then its acceleration will be:**
(a) Positive (b) Negative
(c) Uniform (d) Variable

22. **If the velocity of a body is uniform then its acceleration will be:**
(a) Positive (b) Negative
(c) Zero (d) Doubled

23. **SI unit of acceleration is:**
(a) ms^{-1} (b) kmh^{-1}
(c) kms^{-2} (d) ms^{-2}

24. **If velocity of a body changes equally in equal intervals of time then its acceleration will be:**
(a) Uniform (b) Variable
(c) Constant (d) Relative

25. **The velocity and acceleration of a body moving with uniform speed in a circular path will be:**
(a) In the same direction (b) In the opposite direction
(c) Mutually perpendicular (d) Equal

26. **The direction of motion of body and acceleration is in same direction then acceleration will be:**
(a) Uniform (b) Positive
(c) Negative (d) Zero

27. **The direction of motion of body and acceleration is in opposite direction then acceleration will be:**
(a) Uniform (b) Positive
(c) Negative (d) Zero

28. **The quantity which can be described by a number, with suitable unit only is called:**
(a) Vector (b) Scalar
(c) Speed (d) Acceleration

29. **The quantity which are described by magnitude as well as direction is called:**
(a) Vector (b) Scalar
(c) Speed (d) Acceleration

30. **In equations of motion, motion will always be taken along ---------- line:**
(a) Circular (b) Straight
(c) Elliptical (d) None of above

31. **In equations of motion, Acceleration will always be:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

32. **In equations of motion, initial velocity will be taken as:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

33. **In equations of motion, quantities in the direction of initial velocity are taken as:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

34. **In equations of motion, quantities opposite to the direction of initial velocity are taken as:**
(a) Uniform (b) Variable
(c) Positive (d) Negative

35. **The slope of straight line in speed time graph gives the magnitude of**
(a) Force (b) Displacement
(c) Torque (d) Acceleration

36. **Series of experiments on free fall of heavy bodies was performed by:**
(a) Newton (b) Einstein
(c) Galileo (d) Al-Kundi

37. **When a body is falling freely under the gravity then in equations of motion 'a' is replaced by:**
(a) m (b) d
(c) S (d) g

38. **If a body is falling under the gravity then its initial velocity will be:**
(a) Positive (b) Negative
(c) uniform (d) Zero

39. **If a body is falling under the gravity then its gravitational acceleration will be:**
(a) Positive (b) Negative
(c) Increasing (d) Zero

40. **If a body is thrown vertically upward then its final velocity will be:**
(a) Positive (b) Negative
(c) uniform (d) Zero

41. **If a body is thrown upward, then its gravitational acceleration will be:**
(a) Positive (b) Negative
(c) Increasing (d) Zero

42. **A ball is dropped from the top of the tower. The distance covered by it in the first second is:**
(a) 100m (b) 10m
(c) 50m (d) 5m

43. **If a car is moving with uniform speed in a circle then its velocity will be:**
(a) Uniform (b) Variable
(c) Zero (d) None of the above

44. **There are ------------- equations of motion which are used to solve the problems about the motion of bodies:**
(a) 1 (b) 2
(c) 3 (d) 4

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	d	11	b	21	b	31	a	41	b
2	a	12	d	22	c	32	c	42	d
3	a	13	a	23	d	33	c	43	b
4	b	14	b	24	a	34	d	44	c
5	d	15	a	25	c	35	d		
6	a	16	c	26	b	36	c		
7	c	17	a	27	c	37	d		
8	b	18	b	28	b	38	d		
9	b	19	d	29	a	39	a		
10	d	20	a	30	b	40	d		

Unit 2: Kinematics

Problems

2.1 A train moves with a uniform velocity of 36 kmh^{-1} for 10s. Find the distance traveled by it.

Given Data

Velocity of train = V = 36 kmh^{-1} = $\frac{36 \times 1000}{3600}$ = 10 ms^{-1}

Time taken = t = 10 s

Required

Distance travelled by train = S = ?

Solution

As we know that

$S = V \times t$

By putting the values, we have

$S = 10 \times 10$

$S = 100$ m

Result

Distance travelled by train = S = 100 m

2.2 A train starts from rest. It moves through 1 km in 100s with uniform acceleration. What will be its speed at the end of 100s.

Given Data

Initial velocity of train = v_i = 0 ms^{-1}

Distance covered by train = S = 1 km = 1000 m

Time taken by train = t = 100 s

Required

Speed of train after 100 s = v_f = ?

Solution

First we have to find the acceleration, as we know that

$S = v_i t + \frac{1}{2} at^2$

By putting the values, we have

$1000 = 0 \times 100 + \frac{1}{2} \times a \times (100)^2$

$1000 = \frac{1}{2} \times a \times 10000$

$1000 = a \times 5000$

$a = \frac{1000}{5000}$

So, $a = 0.2$ ms^{-2}

Now from first equation of motion, we have

$v_f = v_i + at$

by putting the values, we have

$v_f = 0 + 0.2 \times 100$

$v_f = 20\ ms^{-1}$

Result

Speed of train after 100 s = v_f = 20 ms^{-1}

2.3 A car has a velocity of 10 ms^{-1}. It accelerates at 0.2 ms^{-2} for half minute. Find the distance traveled during this and the find velocity of the car.

Given Data

Velocity of the car = vi = 10 ms^{-1}

Acceleration of the car = a = 0.2 ms^{-2}

Time taken by car = t = 0.5 min. = 0.5 x 60 = 30 s

Required

Distance traveled by car = S = ?

Solution

As we know that

$S = v_i t + \frac{1}{2} at^2$

By putting the values, we have

$S = 10 \times 30 + \frac{1}{2} \times 0.2 \times (30)^2$

$S = 300 + 0.1 \times 900$

$S = 300 + 90$

$S = 390\ m$

Result

Distance traveled by car = S = 390 m

2.4 A tennis ball is hit vertically upward with a velocity of 30 ms^{-1}. It takes 3 s to reach the highest point. Calculate the maximum height reached by the ball. How long it will take to return to ground?

Given Data

Initial velocity of the tennis ball = vi = 30 ms^{-1}

Time to reach the maximum height = t = 3 s

Gravitational acceleration = g = -10 ms^{-2}

Final velocity of the ball = v_f = 0ms^{-1}

Required

Maximum height reached by the ball = h = ?

Solution

From second equation of motion in vertical motion, we have

$h = v_i t + \frac{1}{2} gt^2$

by putting the values, we have

$h = 30 \times 3 + \frac{1}{2} \times (-10)\ (3)^2$

$h = 90 - 5 \times 9$

$h = 90 - 45$

$h = 45\ m$

As the ball moves with uniform acceleration in vertical motion, so time taken by the ball in both directions will be same.

Total time taken to return the ground = Time taken upwards + Time taken downwards
Total time taken to return the ground = 3 s + 3s
Total time taken to return the ground = 6 s

Result

Maximum height reached by the ball = h = 45 m
Total time taken to return the ground = 6 s

2.5 A car moves with uniform velocity 40 ms^{-1} for 5 s. it comes to rest in the next 10 s with uniform declaration. Find
i) declaration
ii) total distance traveled by the car

Required

(i) Deceleration = $\vec{a}$ = ?
(ii) Distance traveled by the car = S = ?

Solution

(i) Slope of line BC = $\dfrac{y_2 - y_1}{x_2 - x_1}$

$$\vec{a} = \frac{0-40}{15-5} = \frac{-40}{10} = -4ms^{-2}$$

(ii) Area of trapezium OABC = $\dfrac{1}{2}$ (sum of parallel sides)(perpendicular distance between parallel sides)

$$S = \frac{1}{2}(AB + OC)(OA)$$

$$S = \frac{1}{2}(5+15)(40)$$

$$= \frac{1}{2}(20)(40)$$

$$S = \frac{800}{2}$$

$$S = 400\,m$$

Result

Total distance moved by car = S = 400 m

2.6 A train start from rest with an acceleration of 0.5 ms^{-2}. Find its speed in kmh^{-1}, when it has moved through 100 m.

Given Data

Acceleration of the train = a = 0.5 ms^{-2}
Initial velocity of the train = v_i = 0 ms^{-1}
Distance moved by train = S = 100 m

Required

Final speed in kmh^{-1} = v_f = ?

Solution

From third equation of motion, we have

$$2aS = vf^2 - vi^2$$

by putting the values, we have

$$2 \times 0.5 \times 100 = vf^2 - (0)^2$$

$100 = v_f^2$

by taking square root on both sides, we have

$\sqrt{100} = v_f^{\ 2}$

So $\quad v_f = 10\ ms^{-1}$

In kmh-1

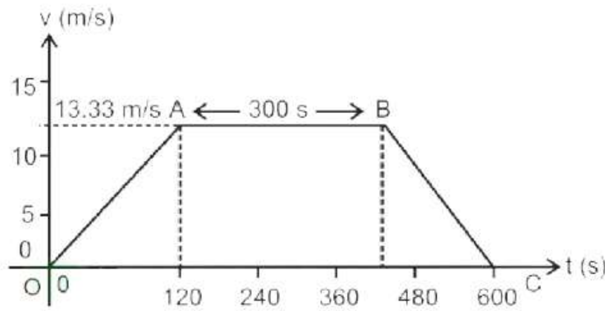
$$v_f = \frac{10 \times 3600}{1000}$$

$v_f = 36\ kmh^{-1}$

Result

Final speed in kmh^{-1} = v_f = 36 kmh^{-1}

2.7 A train starting from rest accelerates uniformly and attains a velocity 48 kmh^{-1} in 2 minutes. It travels at speed for 5 minutes. Finally, it moves with uniform retardation and is stopped after 3 minutes. Find the total distance traveled by the train.



Solution

Total distance covered=?

By using the given values we plot a graph shown in figure.

Velocity = 48 kmh^{-1}

$$= \frac{48 \times 1000}{3600}$$

$$= \frac{40}{3} ms^{-1}$$

time = 2 minutes

= 2(60)

= 120 S

Again time = 5 minutes

= 5(60)

= 300 S

Again time = 3 minutes

= 3(60)

= 180 S

We know that area under speed-time graph represents the distance covered by the object.

$\therefore$ Total distance covered = Area of trapezium OABC

$$= \frac{1}{2} \text{ (sum of parallel sides) (perpendicular distance between parallel sides)}$$

$$= \frac{1}{2}(600+300)\left(\frac{40}{3}\right)$$

$$= \frac{1}{2}(900)\left(\frac{40}{3}\right)$$

Total distance covered = 6000 m

Result

2.8 A cricket ball is hit vertically upwards and returns to ground 6 s later. Calculate
(i) Maximum height, reached by the ball.
(ii) Initial velocity of the ball.

Given Data

Final velocity of the ball = $v_f = 0\ ms^{-1}$
Gravitational acceleration = $g = -10\ ms^{-2}$
Time in which ball return to ground = $t = 6$ s

Required

Maximum height reached by ball = h = ?
Initial velocity of the ball = v_i = ?

Solution

We know that for ball thorwn vertically upward in air
Time taken by ball to reach maximum height = Time taken by ball to reach ground from maximum height
$\therefore$ time taken by ball to reach maximum height = t = 3 s
From first equation of motion, we have

$$v_f = v_i + gt$$

By putting the values, we have

$$0 = v_i + (-10) \times 3$$
$$0 = v_i - 30$$

So $v_i = 30\ ms^{-1}$

Now from second equation of motion, we have

$$S = v_i t + \tfrac{1}{2} gt^2$$

By putting the values, we have

$$S = 30 \times 3 + \tfrac{1}{2} \times (-10) \times (3)^2$$
$$S = 90 - 5 \times 9$$
$$S = 45\ m$$

Result

Maximum height reached by ball = h = 45 m
Initial velocity of the ball = $v_i = 30\ ms^{-1}$

2.9 When brakes are applied, the speed of a train decreases from 96 kmh^{-1} to 48 kmh^{-1} in 800 m. How much further will the train move before coming to rest? (Assuming the retardation to be constant)

Given Data

Initial velocity of train = $v_i = 96\ kmh^{-1} = \dfrac{96 \times 1000}{3600} = \dfrac{80}{3} ms^{-1}$

Final velocity of train = $v_f = 48\ kmh^{-1} = \dfrac{48 \times 1000}{3600} = \dfrac{40}{3} ms^{-1}$

Distance covered by train = 800 m

Required

Retardation of the train = a = ?

Solution

From third equation of motion, we have

$$2aS = v_f^2 - v_i^2$$

By putting the values, we have

$$2a\,(800) = \left(\frac{40}{3}\right)^2 - \left(\frac{80}{3}\right)^2$$

$$1600\,a = \frac{1600}{9} - \frac{6400}{9}$$

$$1600\,a = \frac{1600 - 6400}{9}$$

$$1600\,a = -\frac{4800}{9}$$

$$a = -\frac{4800}{9 \times 1600}$$

$$a = -\frac{1}{3}\,\text{ms}^{-2}$$

Again

Initial velocity of train = v_i = 48 $kmh^{-1} = \frac{40}{3}\,ms^{-1}$

Final velocity of train = v_f = 0 ms^{-1}

retardation of train = a = $-\frac{1}{3}\,ms^{-2}$

Required

Distance covered by train = S = ?

Solution

From third equation of motion, we have

$$2aS = v_f^2 - v_i^2$$

By putting the values, we have

$$2\left(-\frac{1}{3}\right)S = (0)^2 - \left(\frac{40}{3}\right)^2$$

$$-\frac{2}{3}S = -\frac{1600}{9}$$

$$S = \frac{1600}{9} \times \frac{3}{2}$$

$$S = 266.66\,\text{m}$$

Result

The train will move by 266.66 m before coming to rest

2.10 In the above problem, find the time taken by the train to stop after the application of the brakes.

Given Data

Initial velocity of train = v_i = 96 kmh^{-1} = $\frac{96 \times 1000}{3600} = \frac{80}{3}\,ms^{-1}$

Final velocity of train = v_f = 0 ms^{-1}

retardation of train = a = $-\frac{1}{3}\,ms^{-2}$

Required

Time taken by the train = t = ?

Solution

From first equation of motion, we have

$$v_f = v_i + at$$

By putting the values, we have

$$0 = \frac{80}{3} + \left(-\frac{1}{3}\right)t$$

$$0 = \frac{80}{3} - \frac{t}{3}$$

$$\frac{t}{3} = \frac{80}{3}$$

$$t = \frac{80}{3} \times 3$$

$$t = 80\text{s}$$

Result

Required time is 80 s.

Unit 3: Dynamics

Textbook Exercise Questions

3.1 Encircle the correct answer from the given choices.

i. Newton's first law of motion is valid only in the absence of: (LHR 2014, GRW 2015)

(a) Force (b) **net force ✓**
(c) friction (d) momentum

ii. Inertia depends upon:

(a) Force (b) net force
(c) **mass ✓** (d) velocity

iii. A boy jumps out of a moving bus. There is a danger for him to fall:

(a) Towards the moving bus (b) Away from the bus
(c) **In the direction of motion ✓** (d) Opposite to the direction of motion

iv. A string is stretched by two equal and opposite forces of 10 N each. The tension in the string is:

(a) Zero (b) 5 N
(c) **10 N ✓** (d) 20 N

v. The mass of a body

(a) Decreases when accelerated (b) Increases when accelerated
(c) Decreases when moving with high velocity (d) **None of the above ✓**

vi. Two bodies of masses m_1 and m_2 attached to the ends of an inextensible string passing over a frictionless pulling such that both move vertically. The acceleration of the bodies is:

(a) $a = \frac{(m_1 - m_2)g}{m_1 + m_2}$ ✓ (b) $a = \frac{m_1 g}{m_1 + m_2}$

(c) $a = \frac{(m_1 + m_2)g}{m_1 - m_2}$ (d) $a = \frac{m_2 g}{m_1 + m_2}$

vii. Which of the following is the unit of momentum?

(a) Nm (b) $kgms^{-2}$
(c) **Ns ✓** (d) Ns^{-1}

viii. When horse pulls a cart, the action is on the:

(a) Cart (b) earth
(c) horse (d) **earth and cart ✓**

ix. Which of the following material lowers friction when pushed between metal plates? (LHR 2014, 2015)

(a) Water (b) fine marble powder
(c) air (d) **oil ✓**

3.2 Define the following terms:

i) Inertia **ii) Momentum** **iii) Force**

iv) Force of friction **v) Centripetal force**

i. <u>Inertia</u>

Ans: Inertia of a body is its property due to which it resists any change in its state of rest or of uniform motion.

It depends on the mass of the body. Greater the mass of the body greater will be the inertia. Therefore, we can say that mass is the direct measure of inertia.

ii. <u>Momentum</u>

Ans: Momentum of a body is the quantity of motion it possesses due to its mass and velocity.

The momentum 'P' of a body is given by the product of its mass m and velocity v. Thus

$P = m \times v$

Quantity

Momentum is a vector quantity.

Unit

SI unit of momentum is kg ms^{-1} or Ns.

iii. <u>Force</u>

Ans: A force moves or tends to move, stops or tends to stop the motion of a body. The force can also change the direction of motion of a body.

Example

We can open the door either by pushing or pulling the door.

A man pushes the cart. The push may move the cart or change the direction of its motion or may stop the moving cart.

A batsman changes the direction of moving ball by pushing it with his bat.

iv. <u>Force of friction</u>

Ans: The force which opposes the motion of moving objects is called friction.

Friction is force that comes into action as soon as body is pushed or pulled over the a surface.

Factor on which friction depends

In case of solids, the force of friction between two bodies depends upon many factors such as nature of the two surfaces in contact and the pressing force between them.

v. <u>Centripetal force</u>

Ans: **Definition**

The force which compels a body to move away from circular path is known as centrifugal force. This is reaction of centripetal force.

Example

Consider a stone tied with a string moving in a circle. The necessary centripetal force acts on the stone through the string that keeps it in the move in a circle. According to Newton's

third law of motion, there exists a reaction to centripetal force. Centripetal reaction that pulls the string outward is sometimes the centrifugal force.

3.3 What is the difference between?

i) Mass and weight

Differentiate between Mass and Weight.

Mass	Weight
• Mass of a body is the quantity of matter possessed by the body. • It is a scalar quantity. • It is measured by physical balance. • It remains same everywhere. It does not change with change of place. • Unit of mass is kilogram (Kg). • It is a base quantity. • It can be calculated by using the formula F = ma.	• The weight of the body is equal to the force with which earth attracts it. • It is a vector quantity and is toward the center of the earth. • It is measured by spring balance. • It does not remains same at all places because the value of 'g' does remain same at all places. • Unit of weight is Newton (N). • It is a derived quantity. • It can be calculated by using the formula w = mg.

ii) Action and reaction

When two bodies come in contact with each other, the force exerted by first body on second body is known as action.

When two bodies come in contact with each other, the force exerted by second body on first body is known as reaction.

iii) Sliding friction and rolling friction **(GRW 2015)**

Sliding Friction	Rolling Friction
Frictional force experienced by the body when a body slides over the other body. It is greater than rolling friction	Frictional force experienced by the body when a body rolls over the other body. It is less than sliding friction

3.4 What is the law of inertia?

Ans: Since Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as law of inertia.

3.5 Why is it dangerous to travel on the roof of a bus?

Ans: It is dangerous to travel on the roof of a bus because when brakes are applied suddenly, the lower part of body of passenger sitting on its roof comes to rest immediately but due to inertia upper part of his body continues its motion in a straight line and he may fall forward and gets injured if there is no support.

3.6 Why does a passenger moves outward when a bus takes a turn?

Ans: When the bus traveling in a straight line suddenly takes a turn, the passenger in the bus due to inertia tends to continue his motion in the straight line and falls in the forward direction.

3.7 How can you relate a force with the change of momentum of a body?

Ans: See Q.no.6 Long Question

3.8 What will be the tension in a rope that is pulled from its ends by two opposite forces 100 N each?

Ans: The tension in a rope that is pulled from its ends by two opposite forces 100 N each will be 100 N.

3.9 Action and reaction are always equal and opposite then how does a body move?

Ans: Action and reaction are equal in magnitude but opposite in direction. Action and reaction do not act on the same body. Action is applied on one body due to which an equal and opposite reaction is acting on another body. Both of these do not neutralize each other due to which the body will move.

3.10 A horse pushes the cart. If the action and reaction are equal and opposite then how does the cart move?

Ans: The horse apply action on the road by his feet, the reaction is given by the road on the horse, due to which horse moves. The cart which is tied with the horse will also move.

3.11 What is the law of conservation of momentum?

Ans: The momentum of an isolated system of two or more than two interacting bodies remains constant.

An isolated system is a group of interacting bodies on which no external force is acting. If no unbalanced or net force acts on a system then its momentum remains constant.

3.12 Why is the law of conservation of momentum important?

Ans: Law of conservation of momentum has vast applications and is applicable universally on bigger bodies as well as on atoms and molecules. A system of gun and bullet, rocket and jet engines etc. Work on the principle of law of conservation of momentum.

3.13 When a gun is fired, it recoils. Why?

Ans: Total momentum of the gun and the bullet is zero before the firing. When gun is fired, bullet moves in forward direction and gun recoils to conserve momentum.

3.14 Describe two situations in which force of friction is needed?

Ans:

(i) We cannot write if there would be no friction between paper and the pencil.

(ii) Friction enables us to walk on the ground. We cannot run on a slippery ground. A slippery ground offers very little friction.

3.15 How does oiling the moving parts of a machine lower friction?

Ans: As the friction of liquids is less than friction of solids. So oiling the moving parts of the machines lower the friction.

3.16 Describe ways to reduce friction. **(LHR 2014)**

Ans: The friction can be reduced by:

- Making the sliding friction smooth
- Making the fast moving a streamline shape (fish shape) such as car, aeroplanes, etc. this causes the smooth flow of air and thus minimizes air resistance at high speeds.
- Lubricating the sliding surfaces
- Using ball bearings or roller bearings. Because the rolling friction is lesser than the sliding friction.

3.17 Why rolling friction is less than sliding friction? **(LHR 2013, 2014)**

- We know that greater the points of contact between two surfaces, greater will be the friction and vice versa. Since the points of contact between surfaces in case of rolling are

less than points of contact in case of sliding therefore rolling friction is less than sliding friction.

- There is no relative motion between rolling surfaces.

Unit 3: Dynamics

Long Questions

3.2 NEWTON'S LAWS OF MOTION

Newton's First Law of Motion

Q.1 State and Explain Newton's First law of motion (GRW 2011, 2012, 2014)

Ans: A body continues in its state of rest or of uniform motion in a straight line provided no net force acts on it.

Explanation for rest

Newton's first law of motion deals with bodies which are either at rest or moving with uniform speed in straight line. According to first law of motion, a body at rest remains at rest provided no net force act on it. This part of the law is true as we observe that objects do not move by themselves unless someone moves them.

Example

A book lying on a table remains at rest as long as no net force acts on it.

Explanation for motion

Similarly, a moving object does not stop moving by itself. A ball rolled on a rough ground stops earlier than that rolled on smooth ground. It is because rough surface offer greater friction. If there would be no force to oppose the motion of the body would never stop.

Example

When its engine of a car moving with uniform velocity is turned off it stops gradually because a net force of friction is acting in the opposite direction causes to stop it.

Law of inertia

Since Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as law of inertia.

Example

Passengers standing in a bus fall forward when its driver applies brakes suddenly. It is because the upper parts of the bodies tend to continue their motion, lower parts of their bodies are in contact with the bus stop with it. Hence, they fall forward.

Newton's Second Law of Motion

Q.2 State and Explain Newton's Second law of motion (GRW 2011, LHR 2012, 2013)

Ans: "When a net force acts upon a body, it produces as acceleration in the body in the direction of force and the magnitude of acceleration is directly proportional to the net force and is inversely proportional to the mass of the body".

Mathematical Form

If the force 'F' is acting on the body of mass 'm' then we can write this in the mathematical form as,

$$a \propto F \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$a \propto \frac{1}{m} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

From relation (1) and (2), we have

$$a \propto \frac{F}{m}$$

Changing the sign of proportionality into the sign of equality

$$a = \text{constant} \times \frac{F}{m}$$

$$a = k \times \frac{F}{m}$$

In above equation, according to international system of units if m = 1Kg, $a = 1ms^{-2}$, F = 1N then the value of the constant k will be '1'. So the equation can be written as,

$$a = 1 \times \frac{F}{m}$$

$$F = ma$$

This is the mathematical form of Newton's Second law of motion.

Unit of Force

In the System International, the unit of force is Newton, which is represented by the symbol **'N'**.

Newton

"One Newton is that force which produces an acceleration of 1 ms^{-2} in a body of mass 1 Kg".

This unit of Newton can also be written as,

$$1\text{ N} = 1\text{ kg x } 1\text{ ms}^{-2}$$

$$1\text{ N} = 1\text{ Kgms}^{-2}$$

Q.3 Differentiate between Mass and Weight. (GRW 2011, 2012, LHR 2014, 2015)

Ans:

Mass	Weight
• Mass of a body is the quantity of matter possessed by the body.	• The weight of the body is equal to the force with which earth attracts it.
• It is a scalar quantity.	• It is a vector quantity and is toward the center of the earth.
• It is measured by physical balance.	• It is measured by spring balance.
• It remains same everywhere and does not change with change of place.	• It does not remain same at all places and varies with the value of 'g'.
• Unit of mass is kilogram (Kg).	• Unit of weight is Newton (N).
• It is a base quantity.	• It is a derived quantity.
• It can be calculated by using the formula F = ma.	• It can be calculated by using the formula w = mg.
• Mass of a body can never be zero	• Weight of body can be zero

Newton's Third Law of Motion

Q.4 State and Explain Newton's Third law of motion (LHR 2011, GRW 2013)

Ans: To every action there is always an equal but opposite reaction.

Action and Reaction

Newton's third law of motion deals with the reaction of a body when a force acts on it. Let a body A exerts a force on another body B, the body B reacts against this force and exerts a force on body A. the force exerted by body A on B is the action force whereas the force exerted by B on A is called the reaction force.

Relation between Action and Reaction

Newton has expressed action and reaction in his third law of motion. Action is always accomplished by a reaction force and the two forces must always be equal and opposite. It is to remember that "action" and "reaction" do not act on the same body but they act on two different bodies.

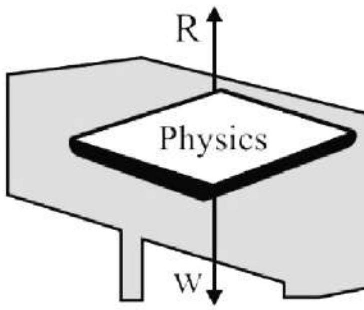


Figure 3.8: Action of the book and reaction on it.

Example 1

Consider a book lying on a table as shown in figure. The weight of the book is acting on the table in the downward direction. This is the action. The reaction of the table acts on the book in the upward direction.

Example 2

Take an air – filled balloon. When the balloon is set free, the air inside it rushes out and the balloon moves forward. In this example, the action is by the balloon that pushes the air out of it when set free. The reaction of the air which escapes out from the balloon acts on the balloon. It is due to this reaction of the escaping air that moves the balloon forward.

Example 3

A rocket moves on the same principle. When its fuel burns, hot gases escape out from its tail with a very high speed. The reaction of these gases on the rocket causes it to move opposite to the gases rushing out of its tail.

Figure 3.10: A Rocket taking off

Tension and Acceleration in a String

Q.5 Explain the tension in the string. If two bodies of masses m_1 and m_2 are hanging from the two ends of a string which is passing over a pulley, find the values of tension and acceleration in it. (LHR 2013, GRW 2015)

Ans: The force which is exerted by the string on the body when its is subjected to a pull is called the tension in the string. It is a reaction force of the weight and it is usually denoted by T. The weight acts downwards while tension T in the string is acting upwards at the block. If the object is at rest, the magnitude of tension is equal to weight.

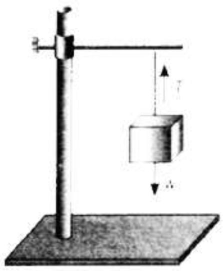


Figure 3.11: Weight of the block pulls the string downwards

Motion of Bodies connected by a string

There are two cases of motion of bodies connected by a string.

(i) When the bodies move vertically

(ii) When one body moves vertically and the other moves horizontally

Case-1

When the Bodies Move Vertically (Atwood machine)

Suppose two bodies A and B having masses m_1 and m_2 respectively are connected to two ends of an inextensible string which passes over a frictionless pulley. If m_1 is greater than m_2, then the body A will move downward and the body B will move upward. The body A being heavier must be moving downwards with some acceleration. Let this acceleration be a. At the same time, the body B attached to the other end of the string moves up with the same acceleration a. as the pulley is frictionless, hence tension will be the same throughout the string. Let the tension in the string be T.

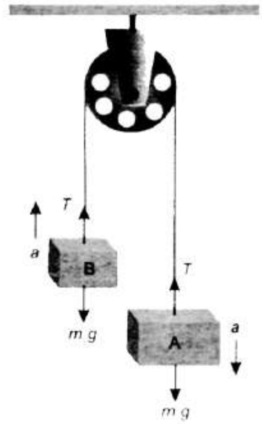


Figure 3.12: Bodies attached to the ends of a string that passes over a frictionless pulley.

Forces acting on the body A

As the body A is moving downward, the resultant force acting on it is downward due to which acceleration a is produced in it.

Net force acting on body A = $F_1 = m_1g - T$

According to Newton's second law of motion;

$$m_1g - T = m_1a \quad \ldots\ldots\ldots\ldots\ldots (1)$$

As the body B is moving upward, the resultant force acting on it is upward due to which acceleration a is produced in it.

Net force acting on body B = $F_2 = T - m_1g$

According to Newton's second law of motion;

$$T - m_2g = m_2a \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Calculation of Acceleration

By adding equation (1) and equation (2), we have

$$m_1g - T + T - m_2g = m_1a + m_2a$$

$$m_1g - m_2g = m_1a + m_2a$$

$$(m_1 - m_2)g = (m_1 + m_2)a$$

$$\frac{(m_1 - m_2)g}{m_1 + m_2} = a$$

OR $$a = \frac{(m_1 - m_2)g}{m_1 + m_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Calculation of Tension

$$\frac{T - m_2g}{m_1g - T} = \frac{m_2a}{m_1a}$$

$$\frac{T - m_2g}{m_1g - T} = \frac{m_2}{m_1}$$

$$m_1\left(T - m_2g\right) = m_2\left(m_1g - T\right)$$

$$m_1T - m_1m_2g = m_1m_2g - m_2T$$

$$m_1T + m_2T = m_1m_2g + m_1m_2g$$

$$\left(m_1 + m_2\right)T = 2m_1m_2g$$

$$T = \frac{2m_1m_2g}{m_1 + m_2}$$

The above arrangement is also known as Atwood machine. It can also used to find the acceleration due to gravity by equation (3)

$$g = \frac{m_1 + m_2}{m_1 - m_2}a$$

Case-II

When One Body Moves Vertically and the Other Moves Horizontally

Two bodies A and B having masses m_1 and m_2 respectively are connected to an inextensible string which passes over the pulley as shown in figure. The body A moves vertically downward with an acceleration a. The body B moves on the horizontal smooth surface towards the pulley with the same acceleration a. As the pulley is frictionless, hence tension T will be the same throughout the string.

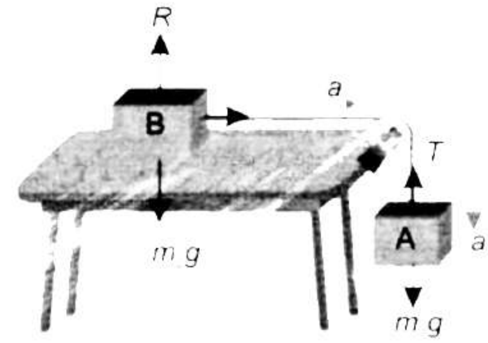


Figure 3.13: Motion of masses attached to a string that passes over a frictionless pulley.

Forces acting on the body A

As the body A is moving downward, therefore, weight m_1g is greater than the tension T in the string.

Net force acting on body A = $m_1g - T$

According to Newton's second law of motion;

$$m_1g - T = m_1a \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Forces acting on the body B

Now consider the motion of the body B. Three forces are acting on it.

(i) Its weight $w_2 = m_2g$ of the body B acting downward

(ii) The upward reaction R on the horizontal surface acting on the body B in the upward direction.

(iii) Tension T on the string pulling the body in the horizontal direction over the smooth surface.

As the body B is not moving vertically, therefore, vertical forces cancel each other and their resultant is zero. The only remaining force T due to which the body B is moving in the horizontal direction with acceleration 'a'.

Hence according to Newton's second law of motion,

$$T = m_2a \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Calculation of Acceleration

Adding eqution (1) and (2)

$$m_1g - T + T = m_1a + m_2a$$

$$m_1g = (m_1 + m_2)a$$

$$a = \frac{m_1g}{m_1 + m_2}$$

Calculation of Tension

In order to find the value of T, put the value of a in equation (2), we have

$$T = m_2 \times \frac{m_1g}{m_1 + m_2}$$

$$T = \frac{m_1m_2g}{m_1 + m_2} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Force and the Momentum

Q.6 How you can prove that rate of change in momentum of a body is equal to the applied force? Or Derive the relation between momentum and force. (LHR 2015)

Ans: When a force acts on a body, it produces an acceleration in the body and will be equal to the rate of change of momentum of the body.

Suppose a force 'F' acts on a body of mass 'm' moving with initial velocity 'v_i' which produces an acceleration a in it. This changes the velocity of body to 'v_f' after time t. If P_i and P_f be the initial momentum and final momentum of the body related to initial and final velocities, Then,

Momentum of the body having velocity $v_i = P_i = mv_i$

Momentum of the body having velocity $v_f = P_f = mv_f$

Change in momentum = final momentum – initial momentum

$$= P_f - P_i = mv_f - mv_i = m(v_f - v_i)$$

$$\text{Rate of change in momentum} = \frac{P_f - P_i}{t} = \frac{mv_f - mv_i}{t}$$

$$\text{Rate of change in momentum} = m\frac{v_f - v_i}{t}$$

Since $\frac{(v_f - v_i)}{t}$ is the rate of change of velocity equal to acceleration produced by the force F.

Rate of change of momentum = ma

According to Newton's second law of motion,

$$F = ma$$

$\therefore$ Rate of change of momentum = F

Rate of change of momentum of a body is equal to the applied force on it and the direction of change of in momentum is in the direction of the force.

Hence when a force acts on a body, it produces an acceleration in the body and will be equal to the rate of change of momentum of the body.

This is statement of Newton's second law of motion in terms of momentum.

Law of Conservation of Momentum

Q.7 State and explain Law of conservation of Momentum. (GRW 2013, LHR 2014)

Ans: The momentum of an isolated system of two or more than two interacting bodies remains constant.

An isolated system is a group of interacting bodies on which no external force is acting. If no unbalanced or net force acts on a system then its momentum remains constant.

Example

Consider the example of an air-filled balloon. In this case, balloon and the air inside it form a system. Before releasing the balloon, the system was at rest and hence the initial momentum of the system was zero. As soon as the balloon is set free, air escapes out of it with some velocity. The air coming out of it possesses momentum. To conserve momentum, balloon moves in the direction opposite to the air coming out of it.

Mathematical Explanation

Consider an isolated system of two spheres of masses m_1 and m_2 as shown figure. They are moving in a straight line with initial velocities u_1 and u_2 respectively, such that u_1 is greater than u_2. Sphere of mass m_1 approaches the sphere of mass m_2 as they move.

Initial momentum of mass $m_1 = m_1u_1$

Initial momentum of mass $m_2 = m_2u_2$

Total momentum of the system before collision $= m_1u_1 + m_2u_2$

After sometime mass m_1 hits m_2 with some force. According to Newton's third law of motion, m_2 exerts an equal and opposite reaction force on m_1. Let their velocities become v_1 and v_2 respectively after collision.

Final momentum of mass $m_1 = m_1v_1$

Final momentum of mass $m_2 = m_2v_2$

Total momentum of the system after collision $= m_1v_1 + m_2v_2$

Total momentum of system before collision = total momentum of system after collision

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

The above equation that the momentum of the isolated system before and after collision remains same which is the law of conservation of momentum.

Application of Law of Conservation of Momentum

This law is applicable universally i.e. true not only for bigger bodies but also for atoms and molecules.

Example

Consider a system of gun and a bullet. Before firing, the velocity of the bullet as well as that of gun was zero. Therefore, the total momentum of both the objects was also zero. We can write it as,

Total momentum of gun and bullet before firing = 0

When the gun is fired, bullet shoots out of the gun and acquire momentum. To conserve momentum the gun recoils backward. Now according to the law of conservation of momentum, the total momentum of the gun and bullet will also be zero after the gun is fired. Let m be the mass of the bullet and v be its velocity on firing the gun; M be the mass of the gun and V be the velocity with which it recoils. Thus the total momentum of the gun is fired will be:

The momentum of the gun and bullet after the gun is fired = $M V + m v$

According to the law of conservation of momentum

Total momentum before firing = Total momentum after firing

$$M V + m v = 0$$

OR $$M V = - m v$$

Hence $$V = -\frac{m}{M} v$$

The above equation gives the velocity V of the gun. Here negative sign indicates that velocity gun is opposite to the velocity of bullet. That is why the shoulder pressed hard during firing. Since mass of the gun is much larger than the bullet, therefore, the recoil is much smaller than the velocity of the bullet.

Application in Rocket or Jet engine

Rocket or Jet engine also works on this same principle. In both of them, gases are produced at a high temperature due to the burning of fuel. These gases rush out with large momentum. Therefore the rockets or jet engines gain an equal and opposite momentum. This enables them to move with very high velocities.

3.3 FRICTION

Q.8 Define friction. Explain cause of friction and derive its mathematical formula.

Ans: The force which opposes the motion of moving objects is called friction.

Cause of friction

No surface is perfectly smooth. A surface that appears smooth has pits and bumps that can be seen under microscope. A magnified view of a surface in contact shows the gaps and contacts between them. The contact points between the two surfaces form a sort of cold welds. These cold welds resist the surfaces from sliding over each other. Adding weight over the upper block increases the force pressing the surfaces together which increases the resistance. Thus greater is the pressing force greater will be the friction between sliding surfaces.

Mathematical Derivation

Friction is equal to the applied force that tends to move a body at rest. This friction at rest is called the static friction. It increases with the applied force. Friction can also be increased to a certain maximum value. It does not increase beyond this. This maximum value of friction

is known as force of limiting friction (Fs). It depends on the normal reaction (pressing force) between the two surfaces in contact. The ratio between the force of limiting friction Fs and the normal reaction R is constant. This constant is called the coefficient of friction and is represented by μ.

Thus $$\mu = \frac{Fs}{R}$$

Or $$Fs = \mu R$$

If m is the mass of the block, then for horizontal surface;

$$R = mg$$

Hence $Fs = \mu\, mg$

Friction is desirable

Friction is needed to walk on the ground. It is risky to run on wet floor with shoes that have smooth soles. Athletes use special shoes that have extraordinary ground grip. Such shoes prevent them from slipping while running fast. To stop bicycle we apply brakes. The rubber pads pressed against the rims provide friction. It is the friction that stops the bicycle.

Rolling Friction

Q.9 Explain the rolling friction.

Ans: Wheel as greatest invention

The most important invention in the history of mankind was a wheel. The first thing about a wheel is that it rolls as it moves rather than to slide. This greater reduces the friction.

Less friction in Rolling Friction

When axle of a wheel is pushed, the force of friction between the wheel and the ground at the point of contact provides the reaction force. The reaction force acts at the contact points of the wheel in a direction opposite to the direction to the applied force. The wheel rolls without rupturing the cold welds. That is why this rolling friction is extremely small than sliding friction. The fact that rolling friction is less than sliding friction is applied in ball bearing to reduce losses due to friction.

Necessary Road Grip

The wheel would not roll on pushing it if there would be no friction between the wheel and the ground. Thus, friction is desirable for wheels to roll over a surface. It is dangerous to drive on a wet road because the friction between the road and the tyres is very small. This increases the chance of slipping the tyres from the road. The threading of tyres is designed to increase friction. Thus, threading improves road grip and make it safer to drive even on wet road.

Sliding Friction in Brakes

A cyclist applies brakes to stop his/her bicycle. As soon as brakes are applied, the wheels stop rolling and begin to slide over the road. Since sliding friction is much greater than rolling friction, the cycle stops very quickly.

Braking and Skidding

Q.10 Explain the roll of friction in Braking and explain the Skidding.

Ans: The wheels of a moving vehicle have velocity components:

(i) Motion of wheel along the road

(ii) Rotation of wheels about their axis

To move a vehicle on the road as well as to stop a moving vehicle requires friction between its tyres and the road.

Example

If the road is slippery or the tyres are worn out then the tyres instead of rolling, slip over the road. The vehicle will not move if the wheels start slipping at the same point on the slippery

road. Thus for the wheels to roll, the force of friction (gripping force) between the tyres and the road must be enough that prevents them from slipping.
Similarly to stop a car quickly, a large force of friction between the tyres and the road is needed. But there is a limit to this force of friction that tyres can provide.

Skidding

If the brakes are applied too strongly, the wheels of the car will lock up (stop turning) and the car will skid due to its large momentum. It will lose its directional control that may result in an accident. In order to reduce the chance of skidding, it is advisable not to apply brakes too hard that lock up their rolling motion especially at high speeds. Moreover, it is unsafe to drive a vehicle with worn out tyres.

3.4 UNIFORM CIRCULAR MOTION

Centripetal Force

Q.11 Define centripetal force and centripetal acceleration and derive the mathematical relation for centripetal force and acceleration.

Ans: A force that keeps a body to move in a circle is known as centripetal force.

Explanation

Consider a body tied at the end of a string moving with uniform speed in a circular path. A body has the tendency to move in a straight line due to inertia. The string to which body is tied keeps it to move in a circle by pulling the body towards the center of the circle. The string pulls the body perpendicular to its motion. The pulling force continuously changes the direction of motion and remains towards the center of the circle. This center seeking force is called the centripetal force. It keeps the body to move in a circle. Centripetal force always acts perpendicular to the motion of the body.

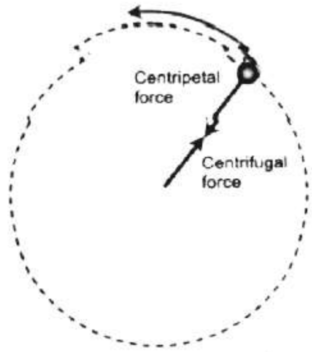


Figure 3.28: Centripetal force acting on the stone and the centrifugal force acting on the

Examples

(i) A stone is tied to one end of a string rotating in a circle. The tension in the string provides the required centripetal force. It keeps the stone to remain in the circle. If the string is not strong enough to provide the necessary tension, it breaks and the stone moves away along the tangent to the circle.

(ii) The moon revolves around the Earth. The gravitational force of the Earth provides required centripetal force.

Mathematical Formula

If an object of mass m is moving with velocity v in a circle of radius r, the magnitude of centripetal force F_c acting on it can be found by using the following equation.

$$F_c = \frac{mv^2}{r}$$

Centripetal acceleration

The acceleration produced by the centripetal force which is always directed towards the center of the circle is known as centripetal acceleration. It is represented by a_c.
According to Newton's second law of motion, the direction of this acceleration is along the direction of the centripetal force F_c, i.e., perpendicular to the velocity and directed towards the centre of the circle.

$$F_c = ma_c$$

So,
$$ma_c = \frac{mv^2}{r}$$

So, $$a_c = \frac{v^2}{r}$$

Dependence

The above equation shows that centripetal force of the body moving in a circular path depends upon:

- Mass m of the body
- Square of its velocity

Unit 3: Dynamics

Multiple Choice Questions

1. **Laws of motion was presented by:**
   (a) Einstein **(b)** Newton
   (c) Galileo **(d)** Archimedes
2. **Isaac Newton described the laws of motion in his famous book:**
   (a) Qanoon-ul-Masoodi **(b)** Principia Mathematica
   (c) Kitab-ul-Astralab **(d)** Al-Manazir
3. **The laws of motion established the relationship between motion and --------:**
   (a) Force **(b)** Torque
   (c) Acceleration **(d)** Momentum
4. **First law of motion is also known as law of ---------------:**
   (a) Torque **(b)** Acceleration
   (c) Inertia **(d)** None of these
5. **--------------- of a body is the direct measure of inertia:**
   (a) Mass **(b)** Energy
   (c) Momentum **(d)** All of above
6. **The characteristic of a body due to which it tends to retain its state of rest or of uniform motion is known as:**
   (a) Weight **(b)** Force
   (c) Inertia **(d)** Momentum
7. **--------------- is the agency which changes or tends to change the state of rest or of uniform motion of a body:**
   (a) Weight **(b)** Force
   (c) Inertia **(d)** Momentum
8. **Law of inertia is actually the ---------- law of motion:**
   (a) First **(b)** Second
   (c) Third **(d)** Fourth
9. **When a force is applied on the body, ------------- is produced in the body:**
   (a) Weight **(b)** Acceleration
   (c) Energy **(d)** None of the above
10. **The acceleration produced in a moving body is always in the direction of applied ---------------:**
    (a) Velocity **(b)** Force
    (c) Speed **(d)** Momentum
11. **If mass of the body is doubled while keeping the force constant, then acceleration will be:**
    (a) One half **(b)** doubled
    (c) One fourth **(d)** Four times
12. **If force applied on the body is doubled while keeping the mass constant, then acceleration will be:**
    (a) One half **(b)** doubled
    (c) One fourth **(d)** Four times

13. **SI unit of force is:**
(a) Kilogram (b) Dynes
(c) newton (d) Pound

14. **When a force of 8 newton is applied on a body of mass 2 kg, then the acceleration produced will be:**
(a) 16 ms^{-2} (b) 4 ms^{-2}
(c) 0.4 ms^{-2} (d) 160 ms^{-2}

15. **1 N = ----------------** **(GRW 2014)**
(a) $kgms^{-2}$ (b) $kgms^{-1}$
(c) kgm^2s^{-1} (d) kg^2ms^{-2}

16. **Action and reaction are equal in magnitude but opposite in direction is known as --------------- law of motion:**
(a) First (b) Second
(c) Third (d) Fourth

17. **Walking on road is an example of ----------------- law of motion:**
(a) First (b) Second
(c) Third (d) Fourth

18. **When a block is lying on a smooth surface, its weight is balanced by:**
(a) Mass (b) Momentum
(c) Inertia (d) Normal Reaction

19. **The weight of a body of mass 10 kg on earth will be ----------------:**
(a) 10 N (b) 1 N
(c) 100 N (d) 1000 N

20. **The ------------ of a body always acting towards the center of the earth:**
(a) Mass (b) Force
(c) Velocity (d) Weight

21. **Quantity of matter in a body:**
(a) Mass (b) Force
(c) Velocity (d) Weight

22. **The Force with which earth attracts a body towards its centre is known as:**
(a) Mass (b) Force
(c) Weight (d) Inertia

23. **The characteristic of a body which determines the magnitude of acceleration produced when a certain force acts upon it:**
(a) Mass (b) Force
(c) Inertia (d) Weight

24. **Mass of the body is measured by:**
(a) Free Fall Apparatus (b) Physical balance
(c) Spring balance (d) All of above

25. **Weight of the body is measured by:**
(a) Free Fall Apparatus (b) Physical balance
(c) Spring balance (d) All of above

26. **Unit of weight is:**
(a) kg (b) ms^{-1}
(c) Nm (d) N

27. **---------------- of a body remains same every where:**
(a) Weight (b) Acceleration
(c) Velocity (d) Mass

28. **--------------- of a body does not remain same every where:**
(a) Weight (b) Inertia
(c) Mass (d) All of above

29. **The value of weight of a body of constant mass depends on:**

(a) Inertia **(b)** Momentum
(c) Force **(d)** 'g'

30. **Mass is a ------------- quantity:**
(a) Scalar **(b)** Vector
(c) Derived **(d)** Negative

31. **Weight is a ------------- quantity:**
(a) Scalar **(b)** Vector
(c) Unitless **(d)** Negative

32. **When a block is hanging with the help of a rope then weight of the body is balanced by:**
(a) Acceleration **(b)** Inertia
(c) Displacement **(d)** Tension

33. **There are -------- cases of motion of the body hanging with the help of rope:**
(a) 1 **(b)** 2
(c) 3 **(d)** 4

34. **The tension produced when one body moves vertically and the other moves horizontally is -------------- as compared to the tension produced when both bodies move vertically:**
(a) Half **(b)** One fourth
(c) Double **(d)** Four times

35. **Quantity of motion in a body is known as:**
(a) Mass **(b)** Momentum
(c) Velocity **(d)** Acceleration

36. **Product of mass and velocity is known as:**
(a) Force **(b)** Speed
(c) Momentum **(d)** Acceleration

37. **SI unit of Momentum is:** **(GRW 2013, LHR 2015)**
(a) $Kgms^{-2}$ **(b)** Ns
(c) $Kgms^{-1}$ **(d)** Both b & c

38. **$Kgms^{-1}$ = -------------**
(a) N **(b)** J
(c) Ns **(d)** W

39. **Rate of change of momentum is equal to:**
(a) Force **(b)** Velocity
(c) Acceleration **(d)** Impulse

40. **Direction of the rate of change of momentum is in the direction of:**
(a) Acceleration **(b)** Momentum
(c) Velocity **(d)** Force

41. **The force which resists the motion of one surface on another surface is known as:**
(a) Gravity **(b)** Friction
(c) Weight **(d)** Repulsion

42. **When object is at rest, the force of friction is known as ------------ friction:**
(a) Static **(b)** Limiting
(c) Kinetic **(d)** Dynamics

43. **The maximum value of static friction is known as ------------ friction:**
(a) Static **(b)** Limiting
(c) Kinetic **(d)** Dynamics

44. **When an object is in motion then the force of friction is known as -----friction:**
(a) Static **(b)** Limiting
(c) Kinetic **(d)** Dynamics

45. **Static friction is -------------- than kinetic friction:**
(a) Less **(b)** Quartered
(c) Greater **(d)** Equal

46. **Rolling friction is -------------- than Sliding friction:**

(a) Inertia (b) Momentum
(c) Force (d) 'g'

30. **Mass is a ------------- quantity:**
(a) Scalar (b) Vector
(c) Derived (d) Negative

31. **Weight is a ------------- quantity:**
(a) Scalar (b) Vector
(c) Unitless (d) Negative

32. **When a block is hanging with the help of a rope then weight of the body is balanced by:**
(a) Acceleration (b) Inertia
(c) Displacement (d) Tension

33. **There are -------- cases of motion of the body hanging with the help of rope:**
(a) 1 (b) 2
(c) 3 (d) 4

34. **The tension produced when one body moves vertically and the other moves horizontally is -------------- as compared to the tension produced when both bodies move vertically:**
(a) Half (b) One fourth
(c) Double (d) Four times

35. **Quantity of motion in a body is known as:**
(a) Mass (b) Momentum
(c) Velocity (d) Acceleration

36. **Product of mass and velocity is known as:**
(a) Force (b) Speed
(c) Momentum (d) Acceleration

37. **SI unit of Momentum is:** **(GRW 2013, LHR 2015)**
(a) $Kgms^{-2}$ (b) Ns
(c) $Kgms^{-1}$ (d) Both b & c

38. **$Kgms^{-1}$ = -------------**
(a) N (b) J
(c) Ns (d) W

39. **Rate of change of momentum is equal to:**
(a) Force (b) Velocity
(c) Acceleration (d) Impulse

40. **Direction of the rate of change of momentum is in the direction of:**
(a) Acceleration (b) Momentum
(c) Velocity (d) Force

41. **The force which resists the motion of one surface on another surface is known as:**
(a) Gravity (b) Friction
(c) Weight (d) Repulsion

42. **When object is at rest, the force of friction is known as ------------ friction:**
(a) Static (b) Limiting
(c) Kinetic (d) Dynamics

43. **The maximum value of static friction is known as ------------ friction:**
(a) Static (b) Limiting
(c) Kinetic (d) Dynamics

44. **When an object is in motion then the force of friction is known as -----friction:**
(a) Static (b) Limiting
(c) Kinetic (d) Dynamics

45. **Static friction is -------------- than kinetic friction:**
(a) Less (b) Quartered
(c) Greater (d) Equal

46. **Rolling friction is -------------- than Sliding friction:**

(a) Less (b) Quartered
(c) Greater (d) Equal

47. **The coefficient of friction has ------------- unit:**
(a) Newton (b) Dynes
(c) No (d) Kilogram

48. **Friction of liquids is -------------- than friction of solids:**
(a) Less (b) Quartered
(c) Greater (d) Equal

49. **Coefficient of friction does not depend upon the ---------- between two surfaces:**
(a) Area of contact (b) Normal Reaction
(c) Weight (d) Roughness

50. **The rolling friction is about ------------ times smaller than sliding friction:**
(a) 10 (b) 50
(c) 100 (d) 1000

51. **Friction in the human joints is much reduced due to the presence of:**
(a) Bones (b) Muscles
(c) Fluid (d) Gas

52. **Value of coefficient of friction (μ_k) depends upon:**
(a) Nature of the surfaces (b) Area of contact
(c) Force (d) All of above

53. **The Rotation of water sprinkler is an example of ---------- law of motion:**
(a) First (b) Second
(c) Third (d) Fourth

54. **A spider web remains intact due to:**
(a) Weight (b) Momentum
(c) Tension (d) None of these

55. **Momentum of a moving body depends upon its:**
(a) Mass (b) Velocity
(c) Weight (d) Both a & b

56. **Motion of the rocket is an example of:**
(a) First law of motion (b) Law of conservation of Momentum
(c) Law of conservation of Energy (d) Weight

57. **Value of coefficient of static friction (μ_s) is usually ------------ than coefficient of kinetic friction (μ_k):**
(a) Less (b) Quartered
(c) Greater (d) Equal

58. **When air is released from an inflated balloon, it shoots off is an example of:**
(a) First law of motion (b) Law of conservation of Energy
(c) Weight (d) Law of conservation of Momentum

59. **Sliding friction is commonly converted into Rolling friction by the use of:**
(a) Ball bearing (b) Oil
(c) Grease (d) Polish

60. **The front sides of high speed vehicles, aeroplanes and ships are shaped wedge like to reduce:**
(a) Weight (b) Pressure
(c) Speed (d) Friction

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	b	11	a	21	a	31	b	41	b	51	c
2	b	12	b	22	c	32	d	42	a	52	a
3	a	13	c	23	a	33	b	43	b	53	c
4	c	14	b	24	b	34	a	44	c	54	c
5	a	15	a	25	c	35	b	45	c	55	d
6	c	16	c	26	d	36	c	46	a	56	b
7	b	17	c	27	d	37	d	47	c	57	c
8	a	18	d	28	a	38	c	48	a	58	d
9	b	19	c	29	d	39	a	49	a	59	a
10	b	20	d	30	a	40	d	50	c	60	d

Unit 3: Dynamics

Problems

3.1 20 N force moves a body with an acceleration of 2 ms^{-2}. What is it its mass? **(LHR 2013)**

Given Data

Force acting on the body = F = 20 N
Acceleration of the body = a = 2 ms^{-2}

Required

Mass of the body = m = ?

Solution

From Newton's second law of motion

$$F = ma$$

So $$m = \frac{F}{a}$$

By putting the values, we have

$$m = \frac{20}{2}$$

$$m = 10\ kg$$

Result

Mass of the body = m = 10 kg

3.2 The weight of a body is 147 N. What is its mass? **(LHR 2013, 2015)**

Given Data

Weight of the body = w = 147 N
Gravitational acceleration = g = 10 ms^{-2}

Required

Mass of the body = m = ?

Solution

As we know that

$$w = mg$$

So $$m = \frac{w}{g}$$

By putting the values, we have

$$m = \frac{147}{10}$$

$$m = 14.7\ kg$$

Result

Mass of the body = m = 14.7 kg

3.3 How much force is needed to prevent a body of mass 10 kg from falling?

Given Data

Mass of the body = 10 kg

Gravitation acceleration = $g = 10\ ms^{-2}$

Required

Force required to prevent the body from falling = R = ?

Solution

As we know that in stable position,

$$R = w = mg$$

By putting the values, we have

$$R = w = 10 \times 10$$

$$R = 100\ N$$

Result

Force required to prevent the body from falling = R = 100 N

3.4 Find the acceleration produced by a force of 100 N in a mass of 50 kg. (GRW 2013)

Given Data

Force acting on the body = F = 20 N

Mass of the body = m = 50 kg

Required

Acceleration of the body = a = ?

Solution

From Newton's second law of motion

$$F = ma$$

So $$a = \frac{F}{m}$$

By putting the values, we have

$$a = \frac{100}{50}$$

$$a = 2\ ms^{-2}$$

Result

Acceleration of the body = a = 2 ms^{-2}

3.5 A body has weight 20 N. How much force is required to move it vertically upwards with an acceleration of 2 ms^{-2}.

Given Data

Weight of the body = 20 N

Acceleration of the body = a = 2 ms^{-2}

Gravitational acceleration = $g = 10\ ms^{-2}$

Normal reaction = R = w = 20 N

Required

Force acting on the body moving vertical upward = F = ?

Solution

As we know that

$$w = mg$$

So $m = \frac{w}{g}$

By putting the values, we have

$$m = \frac{20}{10}$$

$m = 2$ kg

From Newton's second law of motion

$F = ma$

By putting the values, we have

$F = 2 \times 2$

$F = 4$ N

Now net force required to move the body upward
= normal reaction + force producing acceleration
= 20 N + 4 N = 24 N

Result

Force acting on the body moving vertical upward = F = 24 N

3.6 Two masses 52 kg and 48 kg are attached to the ends of a string that passes over a frictionless pulley. Find the tension in the string and acceleration in the bodies.

Mass of first body = m_1 = 52 kg

Mass of second body = m_2 = 48 kg

Gravitational acceleration = g = 10 ms^{-2}

Required

Acceleration of the bodies = a = ?

Tension in the string = T = ?

Solution

When the two bodies are moving vertically then acceleration of the bodies is as,

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$a = \frac{(52-48)\times 10}{52+48}$$

$$a = \frac{40}{100}$$

$a = 0.4\ ms^{-2}$

When the two bodies are moving vertically then tension in the string is as,

$$a = \frac{2m_1m_2g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$T = \frac{2\times 52\times 48\times 10}{52+48}$$

$$T = \frac{49920}{100}$$

$T = 499.2$ N = 500 N

Result

Acceleration of the bodies = a = 0.4 ms^{-2}

Tension in the string = T = 500 N

3.7 Two masses 26 kg and 24 kg are attached to the ends of a string which passes over a frictionless pulley. 26 kg is lying over a smooth horizontal table. 24 kg mass is moving vertically downward. Find the tension in the string and the acceleration in the bodies.

Given Data

Mass of the block moving vertically = m_1 = 24 kg
Mass of the block moving along table = m_2 = 26 kg
Gravitational acceleration = g = 10 ms^{-2}

Required

Acceleration of the bodies = a = ?
Tension in the string = T = ?

Solution

When one body is moving vertically and other body is moving horizontally then acceleration of the bodies is as,

$$a = \frac{m_1 g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$a = \frac{24 \times 10}{24 + 26}$$

$$a = \frac{240}{50}$$

$$a = 4.8\ ms^{-2}$$

When the two bodies are moving vertically then tension in the string is as,

$$T = \frac{m_1 m_2 g}{m_1 + m_2}$$

By putting the values in above equation, we have

$$T = \frac{24 \times 26 \times 10}{24 + 26}$$

$$T = \frac{6240}{50}$$

$$T = 124.8\ N = 125\ N$$

Result

Acceleration in bodies = a = 4.8 ms^{-2}
Tension in the string = T = 125 N

3.8 How much time is required to change 22 Ns momentum by a force of 20 N?
(LHR 2014)

Given Data

Change in momentum = $P_f - P_i$ = 22 Ns
Force applied = F = 20 N

Required

Time required = t = ?

Solution

As we know that

$$F = \frac{P_f - P_i}{t}$$

So $$t = \frac{P_f - P_i}{F}$$

By putting the values, we have

$$t = \frac{22}{20}$$

$t = 1.1\ s$

Result

Time required = t = 1.1 s

3.9 How much is the force of friction between a wood block of mass 5 kg and the horizontal marble floor? The coefficient of friction between wood and marble is 0.6.

Given Data

Mass of the block = m = 5 kg
Coefficient of friction = $\mu_s = 0.6$

Required

Force of friction = F_s = ?

Solution

As we know that

$$F_s = \mu_s mg$$

By putting the values, we have

$$F_s = 0.6 \times 5 \times 10$$
$$F_s = 30\ N$$

Result

Force of friction = F_s = 30 N

3.10 How much centripetal force is needed to make a body of 0.5 kg to move in a circle of radius 50 cm with a speed of 3 ms^{-1}? (LHR 2012)

Given Data

Mass of the body = m = 0.5 kg

Radius of the circle = r = 50 cm = 0.5 m

Speed of the body = v = 3 ms^{-1}

Required

Centripetal force = F_c = ?

Solution

As we know that

$$F_c = \frac{mv^2}{r}$$

By putting the values, we have

$$F_c = \frac{0.5 \times (3)^2}{0.5}$$

$$F_c = 9\ N$$

Result

Centripetal force = F_c = 9 N

Unit 4: Turning Effect of Force

Textbook Exercise Questions

4.1 Encircle the correct answer from the given choices.

i. Two equal but unlike parallel forces having different line of action produces:

(a) Torque ✓ | **(b)** couple
(c) Equilibrium | **(d)** neutral equilibrium

ii. The number of forces that can be added by head to tail rule are:

(a) 2 | **(b)** 3
(c) 4 | **(d) any number✓**

iii. The number of perpendicular components of forces are: (LHR 2013)

(a) 1 | **(b) 2 ✓**
(c) 3 | **(d)** 4

iv. A force of 10 N is making an angle of 30° with the horizontal. Its horizontal component will be:

(a) 4 N | **(b)** 5 N
(c) 7 N | **(d) 8.7 N✓**

v. A couple is formed by:

(a) Two forces perpendicular to each other | **(b)** Two like parallel forces
(c) Two equal and opposite forces in the same line
(d) Two equal and opposite forces not in the same line✓

vi. A body is in equilibrium when its:

(a) Acceleration is uniform | **(b)** Speed is uniform
(c) Speed and acceleration is uniform | **(d) Acceleration is zero✓**

vii. A body is in neutral equilibrium when its centre of gravity:

(a) Is at its highest position | **(b)** Is at the lowest position
(c) Keeps its height if displaced ✓ | **(d)** Is situated at its bottom

viii. Racing cars are made stable by:

(a) Increasing their speed | **(b)** Decreasing their mass
(c) Lowering their centre of gravity✓ | **(d)** Decreasing their width

4.2 Define the following:

Ans:

(i) Resultant vector

A resultant force is a single force that has the same effect as the combined effect of all the forces to be added.

(ii) Torque

The rotational effect of a force is measured by a quantity, known as torque.

(iii) Centre of mass

Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

(iv) Centre of gravity

a point where the whole weight of the body appears to act vertically downward is called the centre of gravity of a body.

4.3 Differentiate the following.

(i) Like and unlike parallel forces

Like Parallel Forces	Unlike Parallel Forces
Like parallel forces are the forces that are paralle to each other and have the same direction.	Unlike parallel forces are the forces that are parallel but have direction opposite to each other.

(ii) Torque and Couple

Torque	Couple
"The rotational effect of a force is measured by a quantity, known as torque".	A couple is formed by two unlike parallel forces of the same magnitude but not along the same line.

(iii) Stable and Neutral Equilibrium

Stable Equilibrium	Neutral Equilibrium
"A body is said to in stable equilibrium if after a slight tilt it returns to its previous position".	"If a body remains in its new position when disturbed from its previous position, it is said to be in a state of neutral equilibrium".

4.4 How head to tail rule helps to find the resultant of forces?

Ans: Draw the representative lines of all the force to be added in such a way that head of first force coincides with the tail of second force, head of second force coincides with the tail of third force and so on. The line obtained by joining the tail of first force with the head of last force represent resultant force.

4.5 How can a force be resolved into its rectangular components?

Ans: See Q. no.2 Long Question

4.6 When a body is said to be in equilibrium?

Ans: A body is said to be in equilibrium if no net force acts on it. A body in equilibrium remains at rest or moves with uniform velocity and has no linear acceleration as well as no rotational acceleration.

4.7 Explain the first condition for equilibrium.

Ans: See Q. no.8 Long Question

4.8 Whey there is need of second condition for equilibrium if a body satisfies first condition for equilibrium.

Ans: When two equal and opposite forces act on a body along the same line, it will be in equilibrium and no linear acceleration is produced in it. But when two equal and opposite forces act on a body not along the same line, the body is not in equilibrium because rotational acceleration is produced in the body although first condition is still satisfied. Hence in this case for the body to be in equilibrium second condition is needed.

4.9 What is second condition of equilibrium?

Ans: A body satisfies second condition of equilibrium when the resultant torque acting on it is zero.

4.10 Give an example of a moving body which is in equilibrium.

Ans: A paratrooper coming down with terminal velocity is in equilibrium. This type of equilibrium is known as dynamic equilibrium.

4.11 Think of a body which is at rest but not in equilibrium.

Ans: A ball thrown upward becomes at rest at the top. At this state it is not in equilibrium although it is at rest.

4.12 When a body cannot be in equilibrium due to a single force on it? (LHR 2015)

Ans: A single force acting on a body is not balanced and produces acceleration. Therefore, in the presence of a single force body can not be in equilibrium.

4.13 Why the height of vehicles is kept as low as possible?

Ans: We know that smaller the height of centre of gravity of a body, greater will be its stability. The height of vehicles is kept low to lower their centre of gravity and as a result their stability increases.

4.14 Explain what is meant by stable, unstable, and neutral equilibrium. Give one example in each case.

Ans: See Q. no.9 Long Question

Unit 4: Turning Effect of Force

Long Questions

4.2 ADDITION OF FORCES

Q.No.1 Which method is used for addition of forces? Explain with example.

Ans: Force is a vector quantity. It has magnitude as well direction; therefore forces are not added by ordinary arithmetic rules. They are added by a method known as head to tail rule.

Head to Tail rule

Draw the representative lines of all the vector to be added in such a way that head of first vector coincides with the tail of second vector, head of second vector coincides with the tail of third vector and so on. The line obtained by joining the tail of first vector with the head of last vector represent resultant vector.

Method

The method of addition of two vectors is given below:

- Select the frame of reference and suitable scale and draw the representative of all the vectors according to the scale; such as vector **A** and **B**.
- Take any one of the vectors as first vector e.g. vector **A**. then draw next vector **B** such that its tail coincides with the head of the first vector **A**. Similarly draw the next vector for the third force (if any) with its tail coinciding with the head of the previous vector and so on.

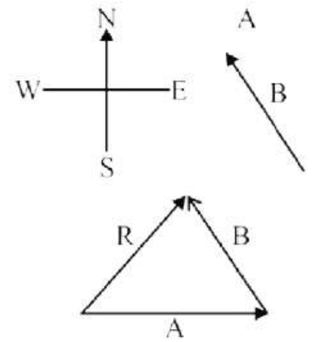


Figure 4.5: Adding vectors by head to tail rule.

- Now draw a vector **R** such that its tail is at the tail of vector **A**, the first vector, while its head is at the head of vector **B**.
- Vector R represents the resultant force completely in magnitude and direction.
- The length of the line according to scale represents the magnitude of the resultant vector.
- The direction of the resultant vector is from the tail of the first vector towards the head of the second.

4.3 RESOLUTION OF FORCES

Q.No.2 Resolve the vector into its rectangular components.

Ans: The decomposition or division of a vector into its components is called resolution of a vector. **OR**

The splitting of a single vector into two mutually perpendicular components is called the resolution of that force.

The process of splitting up vectors (forces) into their component forces is called resolution of force. If a force is formed from two mutually perpendicular components then such components are called **perpendicular components**.

Determination of Rectangular components of a vector

Suppose a vector **F** acts on a body by making an angle θ with the x-axis which is represented by the vector **OA** as shown in the figure. Draw perpendicular from **A** on x-axis as **AB**. According to head to tail rule, **OA** is the resultant vector of **OB** and **BA**.

So **OA = OB + BA** .... (1)

Since the angle between **BA** and **OB** is 90^0, hence these are called the perpendicular components of the vector OA representing F.

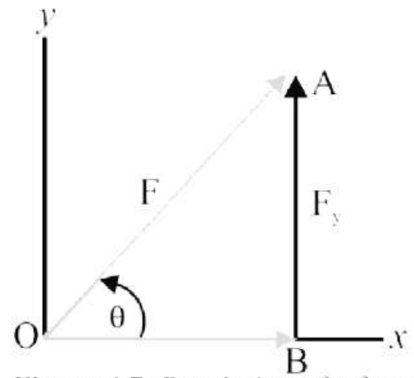


Figure 4.7: Resolution of a force

Horizontal or x-component

The component **OB** along x-axis is represented by $\mathbf{F_x}$ and is called the X-component or horizontal component of the vector **F**.

Vertical or y-component

The component **BA** is represented by $\mathbf{F_y}$ and is called the y-component or vertical component of the vector **F**.

So equation (1) can be represented by,

$$\mathbf{F} = \mathbf{F_x} + \mathbf{F_y}$$

Magnitude of Rectangular components

The magnitude of the perpendicular components F_x and F_y of forces $\mathbf{F_x}$ and $\mathbf{F_y}$ can be found by using the trigonometric ratios. In right angled triangle OAB,

$$\cos\theta = \frac{OB}{OA} \qquad \text{Or} \qquad OB = OA\cos\theta$$

But $OB = F_x$ and $OA = F$

Hence

Similarly,

$$\boxed{\mathbf{F_x = F\cos\theta}}$$

$$\sin\theta = \frac{BA}{OA} \qquad \text{or} \qquad BA = OA\sin\theta$$

But $BA = F_y$ and $OA = F$

Therefore,

$$\boxed{\mathbf{F_y = F\sin\theta}}$$

These two components are the two sides of the right-angled triangle where as hypotenuse represent the magnitude of the actual vector.

Determination of a Force from Its Perpendicular Components

Q.No.3 Find the magnitude and direction of a vector whose rectangular components are given.

Ans: If we have the perpendicular components of any vector then we can find the magnitude and direction of the resultant vector. It is reverse of resolving the vector.

As we know that x-component $\mathbf{F_x}$ of the force **F** is **F cos θ** and the y-component $\mathbf{F_y}$ is **F sin θ**. These two perpendicular components are represented by lines OP and PR respectively as shown in the figure.

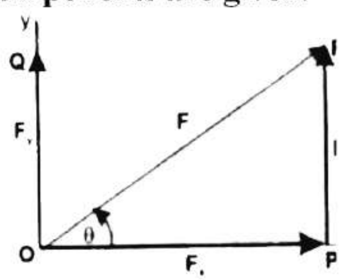


Figure 4.8: Determination of a fc by its perpendicular components

According to head to tail rule:

$$\overrightarrow{OR} = \overrightarrow{OP} + \overrightarrow{PR}$$

Thus $\overrightarrow{OR}$ will completely represent the force $\vec{F}$ where x and y-components are $\overrightarrow{Fx}$ and $\overrightarrow{Fy}$ respectively.

$$\vec{F} = \overrightarrow{Fx} + \overrightarrow{Fy}$$

Magnitude of actual vector

The magnitude of the force F can be determined using the right angled triangle OPR as,

$$(OR)^2 = (OP)^2 + (PR)^2$$

$$F^2 = F_x^2 + F_y^2$$

Hence $F = \sqrt{F_x^2 + F_y^2}$

Direction of actual vector

Direction of the force F with x-axis is given by,

$$\tan\theta = \frac{PR}{OP} = \frac{F_y}{F_x}$$

So $\theta = \tan^{-1}\frac{F_y}{F_x}$

The value of the angle can be determined by using trigonometric tables or calculator.

4.4 TORQUE OR MOMENT OF A FORCE

Q.No.4 Explain torque or moment of a force. **(GRW 2011, LHR 2012)**

Ans: Definition

"The rotational effect of a force is measured by a quantity, known as torque".

Dependence of Torque

Rotation (torque) produced in a body depends on the following two factors:

(i) Force.

(ii) Moment arm

Force

Greater is the force; greater is the moment of the force (torque).

Example

While riding the bicycle, if you press the pedal hard with your feet, its wheels start rotating fast and the speed of the bicycle increases. Similarly if you press the pedal softly, the wheel will rotate slowly and the speed of the bicycle will be less.

Line of action of Force

The line along which a force acts is called the line of action of force. In figure the line BC is the line of action of force.

Moment arm **(LHR 2015)**

The perpendicular distance between the line of action of the force and the axis of rotation, is known as moment arm.

Longer is the moment arm greater is the moment of force.

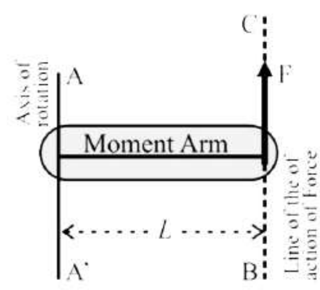


Figure 4.12: Factors affecting the moment of a force

Example

Mechanics loosen or tighten the nut or a bolt with the help of a spanner. A spanner having long arm helps him to do it with greater ease then the one having short arm. It is because the turning effect of the force is different in the two cases. The moment produced by the same force but using a spanner of short arm

Mathematical Form

Torque depends upon the force F and the moment arm r. torque is determined by the product of force F and its moment arm L. So we can write,

Torque = Moment arm x Force

$$\tau = F \times L$$

Unit

In the system international, the unit of torque is Newton meter (Nm). A torque of 1 N m is caused by a force of 1 N acting perpendicular to the moment arm of 1m long.

Sign conventions

Under the action of the torque if the rotation produced is anticlockwise, the torque is considered to be positive. If the rotation produced is clockwise, then the torque is taken as negative.

4.6 CENTRE OF MASS

Q.No.5 What is Centre of Mass? Explain its effect on rotation.

Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

Explanation

It is observed that the centre of mass of a system as if its entire mass is confined that point. A force applied at such a point in the body does not produce any torque in it i.e. the body moves in the direction of net force F without rotation.

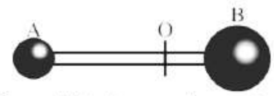


Figure 4.16: Centre of mas of two unequal masses.

Example

Consider a system of two particles A and B connected by a light rigid rod as shown in fig. let O is the point anywhere between A and B such that the force F is applied at point O as shown in fig. if the system moves in the direction of force F without rotation, then point O is the centre of mass of the system.

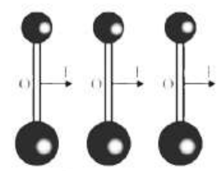


Figure 4.17: A force applied at COM moves the system without rotation.

System move without rotation if the force acts elsewhere on it.

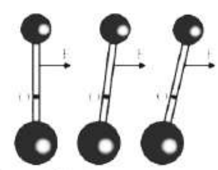


Figure 4.18: The system moves as well as rotates when a force is applied away from COM

(i) Let the force be applied near the lighter particle as shown in fig. the system will move as well as rotate.

(ii) Let the force be applied near the heavier near the heavier particle as shown in fig. in this case, also the system moves as well as rotate.

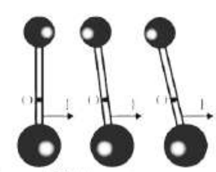


Figure 4.19: The system moves as well as rotates when a force is applied away from COM

4.6 CENTRE OF GRAVITY

Q.No.6 What is meant by centre of gravity of a body? Explain an experiment to find the centre of gravity of a plate of uniform thickness. **(GRW 2014, LHR 2014)**

Ans: A point in a body where the weight of the body appears to act vertically downward is called the centre of gravity.

The centre of gravity can exist inside a body or outside the body. Position of the centre of gravity depends upon the shape of the body.

Method

A body is made up of a large number of particles as shown in figure. Earth attracts each of these particles vertically downwards towards its centre. The pull of the Earth acting on a particle is equal to its weight. These forces acting on the particles of a body are almost parallel. The resultant of all these parallel force is a single force equal to the weight of the body. A point where this resultant force acts vertically towards the centre of the Earth is called the centre of gravity G.

Centre of Gravity of Some Symmetrical Objects

The centre of gravity of objects which have symmetrical shapes can be found from their geometry.

Examples

- The centre of gravity of a uniform rod lies at a point where it is balanced. The balance point is its middle point G.
- The centre of gravity of a uniform square or a rectangular sheet is the point of intersection of its diagonals
- The centre of gravity of a uniform circular disc is its centre
- The centre of gravity of a solid sphere or hollow sphere is the centre of the spheres
- The centre of gravity of uniform triangular sheet is the point of intersection of its medians.
- The centre of gravity of a uniform circular ring is the centre of the ring
- The centre of gravity of a uniform solid or hollow cylinder is the middle point on its axis

Centre of Gravity of an Irregular Shaped Thin Lamina

A simple method to find the centre of gravity of a body is by the use of plumb line. A plumb line consists of small metal bob (lead or brass) supported by a string. When the bob is supported is suspended freely by the string, it rests along the vertical direction due to its weight acting vertically downward as shown in figure. In this state, centre of gravity of the bob is exactly below its point of suspension.

Experiment

Take an irregular piece of cardboard. Make holes A, B and C as shown in the figure near its edge. Fix a nail on a wall. Support the cardboard on the nail through one of the holes (let it be A), so that the cardboard can swing freely about A. the cardboard will come to rest with its centre of gravity just vertically below the nail. Vertical line from A can be located using a plumb line hung from the nail. Mark the line on the cardboard behind the plumb line. Repeat it by supporting the cardboard from hole B. The line from B will intersect at a point G. Similarly, draw another line from the hole C. Note that this line also passes through G. it will be found that all the vertical lines from holes A, B, and C have a common point G. this common point G is the centre of gravity of the cardboard.

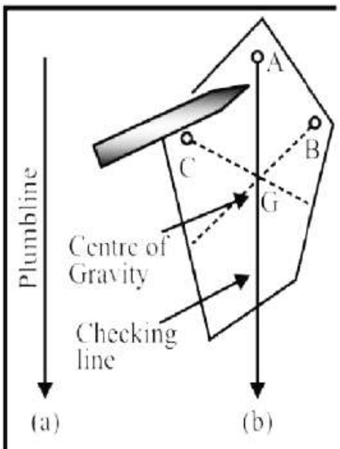


Figure 4.23 (a) Plumbline (b) Loca the centre of gravity of a piece of cardboard by using plumbline.

4.7 COUPLE

Q.No.7 Define Couple. Give examples and find torque produced by couple.

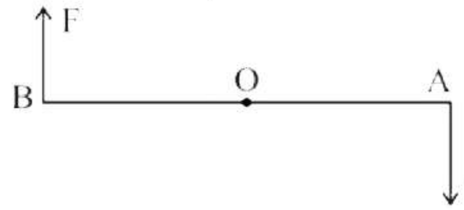
A couple is formed by two unlike parallel forces of the same magnitude but not along the same line.

Examples

- While turning a car, the forces applied on the steering wheel by hands provide the necessary couple.
- While opening or closing a water tap,
- While locking or opening the stopper of a bottle or a jar.

Explanation

A double arm spanner is used to open a nut. Equal forces each of magnitude F are applied on ends A and B of a spanner in opposite direction as shown in figure. These forces form a couple that turns the spanner about a point O. the torques produced by both forces of the couple have same direction. The total torque produced by the couple will be,



Total torque of the couple = F x OA + F x OB

= F (OA + OB)

Torque of the couple = F x AB

The above equation shows that torque produced by the couple of forces F and F separated by distance AB. The toque of a couple is given by the product of one of the two forces and perpendicular distance between them.

Couple arm

The perpendicular distance "r" between the two forces of the couple is called the couple arm.

4.8 EQUILIBRIUM

Q.No.8 What is equilibrium? State and explain the conditions of equilibrium.

Ans: Equilibrium

A body is said to be in equilibrium if no net force acts on it.

First Condition of Equilibrium

A body will be in equilibrium if the resultant of all the forces acting on it is zero. This is first condition of equilibrium.

Explanation

Let n number of forces F_1, F_2, F_3, ..., F_n are acting on a body such that

$F_1 + F_2 + F_3 + \ldots\ldots + F_n$

$\sum F = 0$ .... (1)

The symbol $\sum$ is a Greek letter called sigma used for summation. The first condition of equilibrium can also be stated in terms of x and y-component of the forces on the body as:

$F_{1x} + F_{2x} + F_{3x} + \ldots\ldots + F_{nx} = 0$

And $F_{1y} + F_{2y} + F_{3y} + \ldots\ldots + F_{ny} = 0$

OR $\sum F_x = 0$ .... (2)

$\sum F_y = 0$ .... (3)

Examples

Examples of bodies satisfying the first condition of equilibrium are given below:

Figure 4.27: A wall hanging is in equilibrium

- A book lying on a table or a picture hanging on a wall are at rest
- A paratrooper coming down with terminal velocity (constant velocity)

Linear acceleration

When the 1st condition of equilibrium is satisfied, no linear acceleration is produced in the body.

Second Condition of Equilibrium

If a number of forces act on a body so that the total sum of the torques of these forces is zero, the body will be in equilibrium.

$$\sum \tau = 0 \quad \ldots\ldots\ldots\ldots\ldots (4)$$

This is called the 2nd condition of equilibrium. If these two conditions are satisfied, the body is completely in equilibrium.

Explanation

Consider a body pulled by two forces F_1 and F_2 as shown in figure. The two forces are equal but opposite to each other. Both are acting along the same line, hence their resultant will be zero. According to first condition of equilibrium, the body will be in equilibrium. Now shift the location of the forces as shown in the figure. In this situation, 1 body is not in equilibrium although the first condition of equilibrium is still satisfied. It is because the body has the tendency to rotate. This situation demands another condition for equilibrium in addition to first condition of equilibrium.

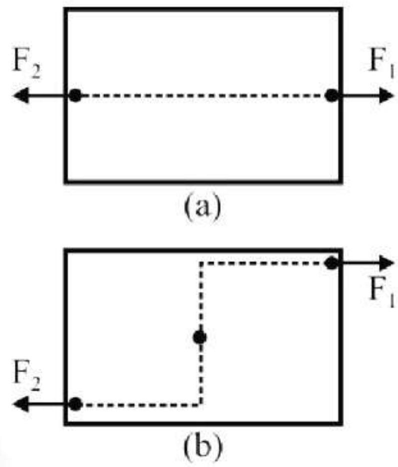


Figure 4.30: (a) Two equal and opposite forces acting along the same lines **(b)** Two equal and opposite forces acting along different lines.

Rotational acceleration

When the 2nd condition of equilibrium is satisfied, then no rotational acceleration is produced in the body.

States of Equilibrium

Q.No.9 Define and explain the three states of equilibrium.

Ans: There are three states of equilibrium:

(i) Stable equilibrium

(ii) Unstable equilibrium

(iii) Neutral equilibrium

Stable equilibrium

A body is said to in stable equilibrium if after a slight tilt it returns to its previous position. When body is in stable equilibrium, its centre of gravity is at the lowest position. When it is tilted, its centre of gravity rises. It returns to its stable state by lowering its centre of gravity. A body remains in stable equilibrium as long as the centre of gravity acts through the base of the body.

Example

Consider a block as shown in figure. When the block is tilted, its centre of gravity G rises. If the vertical line through G passes through its base in the tilted position, the block returns to its previous position. If the vertical line through G gets out its base, it does not return to its previous position.

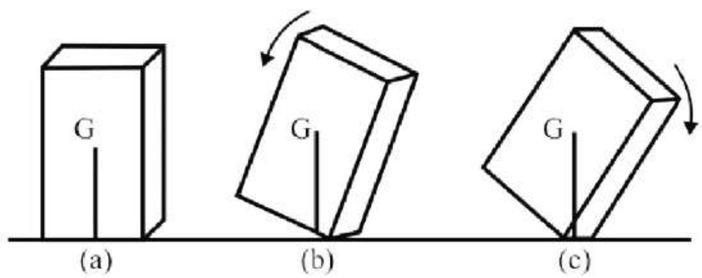


Figure 4.34 (a) Block in stable equilibrium **(b)** Slightly tilted block is returning to its previous position. **(c)** A more tilted block topples over its base and does not return to its previous position.

It topples over its base and moves to new stable equilibrium position. That is why a vehicle made heavy at its bottom to keep its centre of gravity as low as possible. A lower centre of gravity keeps it stable. Moreover, the base of the vehicle is made wide so that the vertical lien passing through the centre of gravity should not get out of its base during a turn.

More Examples

Table, chair, box and brick lying on a floor.

Unstable equilibrium

If a body does not returns to its previous position when sets after a slightest tilt is said to in unstable equilibrium.

The centre of gravity of the body is at its highest point in the state of unstable equilibrium. As the body topples over about its base, its centre of gravity moves towards its lower position and does not return to its previous position.

Example

A pencil is made to stand in equilibrium on its tip. When you leave it, the pencil topples over about its tip and falls down. The body may be made to stay only for a moment. Thus a body is unable to keep itself in the state of unstable equilibrium.

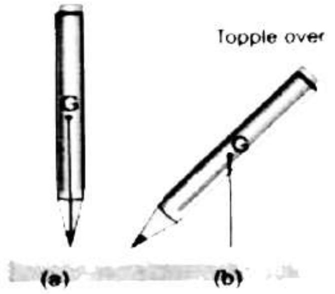


Figure 4.36: Unstable equilibri (a) pencil just balanced at its with centre of gravity G at highest position. (b) Pencil topp over caused by the torque of weight acting at G.

More Examples

- A stick standing vertically on the tip of a finger.
- A cone standing on the tip of a finger.

Neutral equilibrium

If a body remains in its new position when disturbed from its previous position, it is said to be in a state of neutral equilibrium.

Example

A ball lying on a horizontal surface is shown in figure. Roll the ball over the surface and leave it after displacing from the previous position. It remains in its new position and does not return to its previous position.

In neutral equilibrium, the centre of gravity of a body remains at the same height, irrespective of its new position.

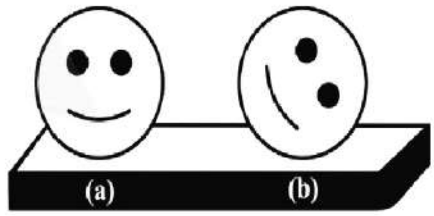


Figure 4.37: Neutral equilibrium (a) a ball is placed on a horizontal surface (b) the ball remains in its new displaced position.

More Examples

A pencil, a sphere, and cylinder, a roller, an egg lying horizontally on a flat surface.

4.9 STABILITY AND POSITION OF CENTRE OF MASS

Q.No.10 How Stability and Position of centre of mass are related to each other?

Ans: As we have learnt that position of centre of mass of an object plays an important role in their stability. To make them stable, their centre of mass must be kept as low as possible. It is due to the reason, racing cars are made heavy at the bottom and their height is kept to be minimum.

Examples

Here are few examples in which lowering of centre of mass makes the objects stable. These objects return to their stable states when disturbed. In each case centre of mass is vertically below their point of support. This makes their equilibrium stable.

- Circus artists such as tight rope walker use long poles to lower their centre of mass. In this way they are prevented from topple over.

- Figure shows a sewing needle fixed in a cork. The cork is balanced on the tip of the needle by hanging forks. The forks lower the centre of mass of the system.

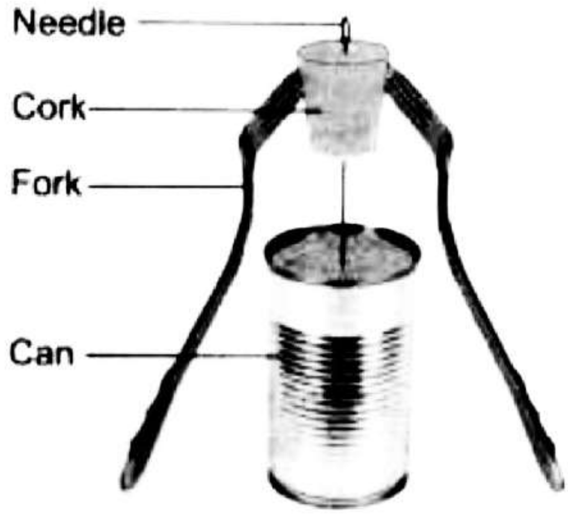
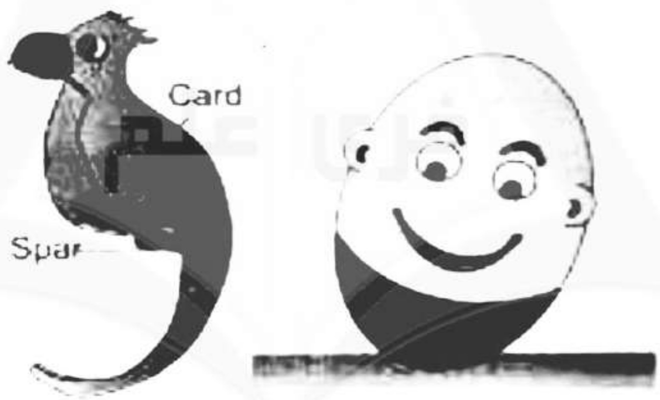


Figure 4.38: A needle is made to balance at its tip.

- Figure shows a perched parrot which is made heavy at its tail. Figure shows a toy that keeps itself upright when tilted. It has heavy semi spherical base. When it is tilted, its centre of mass rises. It returns to the upright position at which its centre of mass is at the lowest.



(a) (b)

Figure 4.39 **(a)** A perched parrot
(b) A self righting toy

Unit 4: Turning Effect of Force

Multiple Choice Questions

1. **If a number of forces act on a body such that their points of action are different but lines of action are parallel to each other then these forces are known as -------------- forces:**
   (a) Same **(b)** Parallel
   (c) Perpendicular **(d)** None of above
2. **If the direction of parallel forces is the same, then these are called ------------------- forces:**
   (a) Same **(b)** Like Parallel
   (c) Unlike Parallel **(d)** All of above
3. **If the direction of parallel forces is the opposite, then these are called ------------------ forces:**
   (a) Same **(b)** Like Parallel
   (c) Unlike Parallel **(d)** All of above
4. **Addition of vectors are done by:**
   (a) Head to tail rule **(b)** Left hand rule
   (c) Right hand rule **(d)** None of above
5. **Component of a vector acting along the x – axis is called:**
   (a) x – component **(b)** horizontal component
   (c) vertical component **(d)** both a and b
6. **component of a vector acting along the y – axis is called:**
   (a) x – component **(b)** horizontal component
   (c) vertical component **(d)** both a and b
7. **Value of sin 30^0:**
   (a) 0.5 **(b)** 0.866
   (c) 0.707 **(d)** none of them
8. **During rotation the particles of the body rotate along fixed circles. The straight line joining the centres of these circles is known as:**
   (a) Parallel line **(b)** Axis of rotation
   (c) Both a & b **(d)** None of above
9. **The rotational effect of a body is measured by a quantity known as:**
   (a) Acceleration **(b)** Velocity
   (c) Displacement **(d)** Torque
10. **The rotation produced in a body depends upon ---------- factors:**
    (a) 1 **(b)** 2
    (c) 3 **(d)** 4
11. **Torque is a -------------- quantity:**
    (a) Base **(b)** Vector
    (c) Scalar **(d)** Both a & b
12. **The direction of torque is determined by ---------------- rule:**
    (a) Left hand **(b)** Right hand
    (c) Both a & b **(d)** None of above

13. **If the rotation produced in anticlock wise direction then the torque is taken as:**
(a) Positive **(b)** Negative
(c) Opposite **(d)** Perpendicular

14. **If the rotation is produced in clock wise direction then the torque is taken as:**
(a) Positive **(b)** Negative
(c) Opposite **(d)** Perpendicular

15. **According to right hand rule, if ------------ is along the curl of the fingers of the right hand then the thumb points in the direction of the torque:**
(a) Rotation **(b)** Parallel
(c) Force **(d)** Weight

16. **In System International, the unit of torque is:**
(a) N **(b)** Nm^{-2}
(c) Nm^{-1} **(d)** Nm

17. **The force which is acting perpendicularly downwards towards the earth is called:**
(a) Torque **(b)** Weight
(c) Force of gravity **(d)** Both b & c

18. **The point at which whole weight of the body appears to act is called:**
(a) Origin **(b)** Couple
(c) Centre of Gravity **(d)** Reference point

19. **The position of the centre of gravity depends upon the ----- of the body:**
(a) Size **(b)** Shape
(c) Weight **(d)** Force

20. **The centre of gravity of parallelogram, rectangle, square is the:**
(a) Point of intersection of the medians **(b)** Central point of axis
(c) Point of intersection of the diagonals **(d)** Centre of parallelogram

21. **The centre of gravity of a regular shaped body is always on its centre of -----------------:**
(a) Body **(b)** Symmetry
(c) Medians **(d)** Axis

22. **The centre of gravity of triangle is the:**
(a) Point of intersection of the medians **(b)** Central point of axis
(c) Point of intersection of the diagonals **(d)** Centre of parallelogram

23. **The centre of gravity of cylinder is the:**
(a) Point of intersection of the medians **(b)** Central point of axis
(c) Point of intersection of the diagonals **(d)** Centre of parallelogram

24. **When two equal, opposite and parallel forces act at two points of the same body, they form a:**
(a) Torque **(b)** Moment of a couple
(c) Force **(d)** Couple

25. **A ------------ is always acting while opening or closing water tap, a lock, stopper of a bottle or jar:**
(a) Couple **(b)** Weight
(c) Force **(d)** Mass

26. **The perpendicular distance between the line of action of force and centre of rotation and denoted by 'r' is called:**
(a) Centre of gravity **(b)** Moment arm
(c) Displacement **(d)** Force

27. **The torque produced in a body due to a couple is equal to the product of one of the forces and the --------------------:**
(a) Couple **(b)** Force
(c) Like parallel force **(d)** Couple arm

28. **There are ------------- conditions of equilibrium:** **(LHR 2013)**
(a) 1 **(b)** 2

(c) 3 **(d)** 4

29. **When the sum of all the force acting on a body is zero or the object is moving with uniform velocity then it will be in -----------------:**

(a) Rest **(b)** Motion

(c) Equilibrium **(d)** None of above

30. **According to First condition of equilibrium, the sum of all the forces acting on the body should be -----------------:**

(a) Positive **(b)** Zero

(c) None **(d)** All of above

31. **First condition of equilibrium is represented by:**

(a) $\sum F = 0$ **(b)** $\sum F_x = 0$

(c) $\sum F_y = 0$ **(d)** All of above

32. **According to Second condition of equilibrium, the sum of all the torques acting on the body should be -----------------:**

(a) Positive **(b)** Zero

(c) None **(d)** All of above

33. **Second condition of equilibrium is represented by:**

(a) $\sum \tau = 0$ **(b)** $\sum F = 0$

(c) Both a & b **(d)** All of above

34. **Sigma ($\sum$) is the Greek letter which is used to represent:**

(a) Addition **(b)** Subtraction

(c) Multiplication **(d)** Division

35. **There are ------------ states of equilibrium:**

(a) 1 **(b)** 2

(c) 3 **(d)** 4

36. **The equilibrium in which the body comes back to its original condition when set free after slightly lifting from one side is --------- equilibrium:**

(a) Stable **(b)** Unstable

(c) Neutral **(d)** None of above

37. **The equilibrium in which the body does not come back to its original condition when set free after slightly lifting from one side is --------- equilibrium:**

(a) Stable **(b)** Unstable

(c) Neutral **(d)** None of above

38. **The type of equilibrium in which after disturbance, the body again comes to rest position and center of gravity remains unchanged:**

(a) Stable **(b)** Unstable

(c) Neutral **(d)** None of above

39. **In Stable equilibrium, the centre of gravity is ------------ than the original position:**

(a) Raised **(b)** Lowered

(c) Remain same **(d)** All of above

40. **In Unstable equilibrium, the centre of gravity is ------------ than the original position:**

(a) Raised **(b)** Lowered

(c) Remain same **(d)** All of above

41. **In Neutral equilibrium, the centre of gravity ------------ than the original position:**

(a) Raised **(b)** Lowered

(c) Remain same **(d)** All of above

42. **When an object is resting on the smooth horizontal surface, the weight of the object is balanced by --------------------:**

(a) Normal Reaction **(b)** Torque

(c) Friction **(d)** Couple

43. **A meter rod on a wedge is an example of ------------ equilibrium**

(a) Stable **(b)** Unstable

(c) Neutral (d) None of above

44. **A book lying on the table is an example of ----------------- equilibrium:**

(a) Stable (b) Unstable
(c) Neutral (d) None of above

45. **Motion of the football on the ground is an example of ------- equilibrium:**

(a) Stable (b) Unstable
(c) Neutral (d) None of above

46. **The ----------- of a racing car is kept low to make its stable:**

(a) Width (b) Height
(c) Length (d) Weight

47. **If the centre of gravity of the body is below the fulcrum then the body will be in --------------- equilibrium:**

(a) Stable (b) Unstable
(c) Neutral (d) None of above

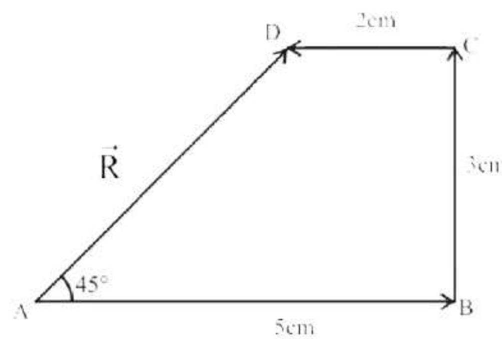
ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	b	11	b	21	b	31	d	41	c
2	b	12	b	22	a	32	b	42	a
3	c	13	a	23	b	33	a	43	b
4	a	14	b	24	d	34	a	44	a
5	d	15	a	25	a	35	c	45	c
6	c	16	d	26	b	36	a	46	b
7	a	17	d	27	d	37	b	47	a
8	b	18	c	28	b	38	c		
9	d	19	b	29	c	39	a		
10	b	20	c	30	b	40	b		

Unit 4: Turning Effect of Force

Problems

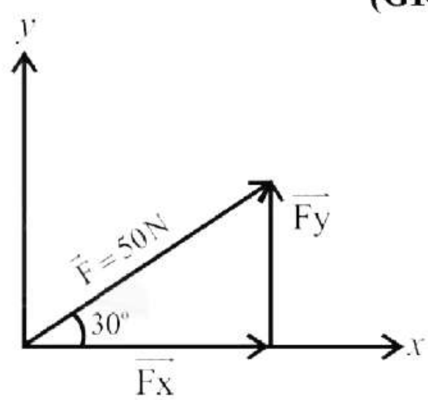
4.1 Find the resultant of the following forces.
(i) 10 N along x – axis
(ii) 6 N along y – axis
(iii)4 N along negative x – axis



Solution

Scale 2N = 1cm
10N = 5cm
6N = 3cm
4N = 2cm

4.2 Find the rectangular components of a force of 50 N making an angle of 30^0 with x – axis. (GRW 2015)



Given Data

Force = F = 50 N
Angle = $\theta = 30^0$

Required

Horizontal component of force = F_x = ?
Vertical component of force = F_y = ?

Solution

As we know that

$F_x = F \cos\theta$

By putting the values, we have

$F_x = 50 \times \cos 30^0$
$F_x = 50 \times 0.866$
$F_x = 43.3$ N

Also we know that

$F_y = F \sin\theta$
$F_y = 50 \times \sin 30^0$
$F_y = 50 \times 0.5$
$F_y = 25$ N

Result

Horizontal component of force = F_x = 43.3 N
Vertical component of force = F_y = 25 N

4.3 Find the magnitude and direction of a force. If its x – component is 12 N and y – component is 5 N. (GRW 2013)

Given Data

X – component of the force = F_x = 12N
Y – component of the force = F_y = 5N

Required

Magnitude of the resultant force = F =?
Direction of the resultant force = θ =?

Solution

According to Pythagoras theorem

$$F = \sqrt{F_x^2 + F_y^2}$$

By putting the values, we have

$$F = \sqrt{(12)^2 + (5)^2}$$
$$F = \sqrt{144 + 25}$$
$$F = \sqrt{169}$$
$$F = 13N$$

We also know that

$$\theta = \tan^{-1}\frac{F_y}{F_x}$$

By putting the values, we have

$$\theta = \tan^{-1}\frac{5}{12}$$
$$\theta = \tan^{-1} 0.4166$$
$$\theta = 22.6^o \text{ with x-axis}$$

Result

Magnitude of the resultant force = F = 13 N
Direction of the resultant force = θ = 22.6° with x-axis

4.4 A force of 100 N is applied perpendicularly on a spanner at a distance of 10 cm from a nut. Find torque produced by the force. (GRW 2013, 2014, 2015)

Given Data

Force acting on spanner = F = 100 N
Distant from nut = L = 10 cm = 0.1 m

Required

Torque produced by the force = τ = ?

Solution

As we know that

$$\tau = F \times L$$

By putting the values, we have

$$\tau = 100 \times 0.1$$
$$\tau = 10 \text{ Nm}$$

Result

Torque produced by the force = τ = 10 Nm

4.5 A force is acting on a body making an angle of 30⁰ with the horizontal. The horizontal component of force is 20 N. Find the force. (LHR 2015)

Given Data

Horizontal component of the force = F_x = 20 N
Angle formed with the horizontal = $\theta = 30^0$

Required

Force applied = F = ?

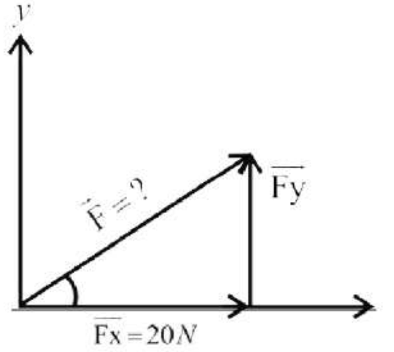
Solution

As we know that

$$F_x = F\cos\theta$$

So $$F = \frac{F_x}{\cos\theta}$$

By putting the values, we have



$$F = \frac{20}{\cos 30^0}$$

$$F = \frac{20}{0.866}$$

$$F = 23.09\ N = 23.1\ N$$

Result

Force applied = F = 23.1 N

4.6 The steering of a car has a radius 16 cm. Find the torque produced by a couple of 50 N.

(LHR 2013, 2014, 2015)

Given Data

Force of the couple = F = 50 N

Radius of the steering = r = 16cm

Couple arm = d = AB = 32 cm = 0.32 m

Required

Torque produced by the couple = τ = ?

Solution

As we know that

$$\tau = F \times AB$$

By putting the values, we have

$$\tau = 50 \times 0.32$$

$$\tau = 16\ Nm$$

Result

Torque produced by the couple = τ = 16 Nm

4.7 A picture frame is hanging by two vertical strings. The tensions in the strings are 3.8 N and 4.4 N. Find the weight of the picture frame.

Given Data

Tension in the first string = T_1 = 3.8 N

Tension in the second string = T_2 = 4.4 N

Required

Weight of the picture frame = w = ?

Solution

From first condition of equilibrium, we have

$$\sum F_y = 0$$

OR Sum of downward forces = Sum of upward forces

$$w = T_1 + T_2$$

By putting the values, we have

$$w = 3.8\ N + 4.4\ N$$

$$w = 8.2\ N$$

Result

Weight of the picture frame = w = 8.2 N

4.8 Two blocks of 5 kg and 3 kg are suspended by the two strings are shown. Find the tension in each string.

Given Data

Mass of upper block = m_1 = 5 kg

Mass of below block = m_2 = 3 kg

Weight of the upper block = $w_1 = m_1g = 5 \times 10 = 50$ N

Weight of the below block = $w_2 = m_2g = 3 \times 10 = 30$ N

Required

Tension in upper string = T_1 = ?

Tension in lower string = T_2 = ?

Solution

From second condition of equilibrium, we have

$$\sum F_y = 0$$

OR Tension in the lower string = weight of the lower block

$$T_2 = w_2$$
$$T_2 = 30\text{ N}$$

Tension in upper string = weight of lower block + weight of upper block

$$T_1 = w_1 + w_2$$
$$T_1 = 50\text{ N} + 30\text{ N}$$
$$T_1 = 80\text{ N}$$

Result

Tension in upper string = T_1 = 80 N
Tension in lower string = T_2 = 30 N

4.9 A nut has been tightened by a force of 200 N using 10 cm long spanner. What length o spanned is required to loosen the same nut with 150 N force?

(LHR 2013, GRW 2014)

Given Data

Initial force = F_1 = 200 N
Initial moment arm = L_1 = 10 cm = 0.1 m
Second force = F_2 = 150 N

Required

Second moment arm = L_2 = ?

Solution

According to second condition of equilibrium, we have

$$\sum\tau = 0$$

OR Clockwise torque = Anticlockwise torque

$$F_2 \text{ x } L_2 = F_1 \text{ x } L_1$$
$$150 \text{ x } L_2 = 200 \text{ x } 0.1$$
$$L_2 = \frac{200 \times 0.1}{150}$$
$$L_2 = 0.133\text{ m}$$
$$L_2 = 13.3\text{ cm}$$

Result

Second moment arm = L_2 = 13.3 cm

4.10 A block of 10 kg is suspended at a distance of 20 cm from the centre of uniform bar 1m long. What force is required to balance it at its centre of gravity by applying the force a the other end of the bar?

Given Data

Mass of block = m = 10kg
Weight of the block = w = F_1= mg = 10 x 10 = 100 N
First moment arm = L_1 = 20 cm = 0.2 m
Second moment arm = L_2 = 50 cm = 0.5 m

Required

Second force = F_2 = ?

Solution

According to second condition of equilibrium, we have

$$\sum\tau = 0$$

OR Clockwise torque = Anticlockwise torque

$$F_2 \text{ x } L_2 = F_1 \text{ x } L_1$$
$$F_2 \text{ x } 0.5 = 100 \text{ x } 0.2$$
$$F_2 = \frac{100 \times 0.1}{0.50}$$
$$F_2 = 40\text{ N}$$

Result

Second force = F_2 = 40 N

Unit 5: Gravitation

Textbook Exercise Questions

5.1 Encircle the correct answer from the given choices.

i. Earth's gravitational force of attraction vanishes at:
(a) 6400 km **(b) infinity** ✓
(c) 42300 km **(d)** 1000 km

ii. Value of g increases with the:
(a) Increase in mass of body **(b)** increase in altitude
(c) decrease in altitude ✓ **(d)** none of the above

iii. The value of g at a height one Earth's radius above the surface of Earth is:
(a) 2 g **(b)**1/2 g
(c) 1/3 g **(d) 1/4 g**✓

iv. The value of g on moon's surface is 1.6 ms^{-2}. What will be the weight of a 100 kg body on the surface of the moon?
(a) 100 N **(b) 160 N** ✓
(c) 1000 N **(d)** 1600 N

v. The altitude of geostationary orbits in which communications satellites are launched above the surface of Earth is:
(a) 850 km **(b)** 1000 km
(c) 6400 km **(d) 42300 km**✓

vi. The orbital speed of a low orbit satellite is:
(a) zero **(b)** 8 ms^{-1}
(c) 800 ms^{-1} **(d) 8000 ms^{-1}**✓

5.2 What is meant by force of gravitation?

Ans: In the universe, there exists a force between the bodies due to which everybody of the universe attracts every other body. This force is known as force of gravitation.

5.3 Do you attract the earth or the Earth attracts you? Which one is attracting with a larger force? You or Earth?

Ans: We attract the earth and Earth attracts us but Earth attracts us with larger force because the mass of the Earth is large.

5.4 What is a field force?

Ans: The gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not is called field force.

5.5 Why earlier scientists could not guess about the gravitational force?

Ans: The early scientists could not guess about the gravitational force due to lack of observations and lack of knowledge. Also it is a very weak force and its presence cannot be detected until mass of one body in much greater than mass of other body.

5.6 How can you say that gravitational force is a field force?

Ans: The gravitational force exists around the Earth and is acting on the bodies whether the bodies are in contact with the Earth or not. So, we can say that gravitational force is a field force.

5.7 Explain, what is meant by gravitational field strength? (LHR 2013)

Ans: In gravitational field, the gravitational force acting per unit mass is called the gravitational field strength. It becomes weaker and weaker as we go away from the object applying the gravitational force.

5.8 Why law of gravitation is important to us?

Ans: Law of gravitation is important to us because it is used to calculate force of attraction between two masses. It is used to calculate the mass of Earth.

5.9 Explain the law of gravitation?

Ans: See Q. no.1 Long Question

5.10 How the mass of Earth can be determined?

Ans: See Q. no.3 Long Question

5.11 Can you determine the mass of our moon? If yes, then what you need to know?

Ans: Yes we can determine the mass of the moon by same method used to measure the mass of the Earth with the help of law of gravitation. The formula is:

$$M_m = \frac{g_m R_m^2}{G}$$

From the about relation it shows that we require,

g_m = gravitational acceleration on the surface of moon

R_m = Radius of moon

G = Gravitational constant

5.12 Why does the value of g vary from place to place? (GRW 2015, LHR 2016)

Ans: We know that

$$g = \frac{GMe}{R^2}$$

The above relation shows that value of 'g' is inversely proportional to the square of distance of body from the centre of earth. Hence when distance body from centre of earth increase, the value of g decreases and vice versa.

5.13 Explain how the value of g varies with altitude.

Ans: See Q. no.4 Long Question

5.14 What are artificial satellites? (LHR 2013)

Ans: Scientists have sent many objects into space. Some of these revolve around the Earth. These are called artificial satellites.

Large numbers of artificial satellites have been launched in different orbits around the Earth. They take different time to complete their one revolution around the Earth depending upon their distance h from the Earth.

5.15 How Newton's law of gravitation helps in understanding the motion of satellites.

Ans: When a satellite moves around the earth in a nearly circular path, the gravitational force of attraction between earth and satellite provides the necessary centripetal force for its motion. This gravitational force can be found by using Newton's law of gravitation and finally we can find orbital speed of satellites.

5.16 On what factors the orbital speed of a satellite depends? (GRW 2015, LHR 2016)

Ans: As we know that

$$v_o = \sqrt{g_h\,(R + h)}$$

So, we can say that orbital speed depends upon the gravitational acceleration and distance between the center of earth and the satellite.

5.17 Why communication satellites are stationed at geostationary orbits? (GRW 2013, 14)

Ans: The satellites in geostationary orbits remain all the time in front of target part of Earth so that direction of receiver's dish do not to be changed.

Unit 5: Gravitation

Long Questions

5.1 THE FORCE OF GRAVITATION

Law of Gravitation

Q.1 State and explain Newton's law of gravitation. (GRW 2011, 12, 13, 15, LHR 2013)

Ans: Gravitation

In the universe, there exists a force between the bodies due to which everybody of the universe attracts every other body. This force is known as force of gravitation.

Statement

Every object in the universe attracts every other object with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.

Explanation

Every object in this universe attracts other objects towards its centre. The attraction between two objects is called gravitation. On the basis of his observations, Newton derived a law which is called Newton's law of gravitation.

Mathematical Derivation

Consider two bodies A and B of masses m_1, and m_2, respectively. According to law of gravitation, the gravitational force of attraction F with which two mass m_1 and m_2 separated by a distance d attracts each other is given by:

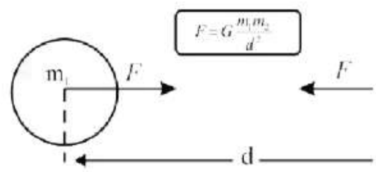


Figure 5.1: Two masses att each other with a gravitatio force of equal magnitude.

$$F \propto m_1m_2$$

$$F \propto \frac{1}{d^2}$$

OR

$$F \propto \frac{m_1m_2}{d^2}$$

$$F = \frac{Gm_1m_2}{d^2}$$

Gravitational constant

G is a constant called gravitational constant. It is called universal constant of gravitation. If $m_1 = m_2 = 1$ kg and $d = 1$ m, then $F = G$. Thus G is a force which 1 kg object exerts on another 1 kg object placed 1 m away from it. In SI units, the value of gravitational constant G is 6.67×10^{-11} Nm^2 kg^{-2}.

Dependence of Gravitational force on mass

Due to small value of G, the gravitational force of attraction between different objects around us is very small, so we do not feel it. However, if the mass of one or both the objects is very large, then we can observe the effect of gravitational force easily.

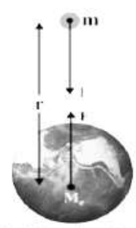


Figure 5.2: Weight of a body is due to the gravitational force between the body and the Earth.

Q.2 Explain the gravitational field? **(GRW 2013)**

Ans: The space around the earth in which its gravitational force acts on a body is called gravitational field. According to the Newton's law of gravitation, the gravitational force between a body of mass m and the Earth is given by,

$$F = \frac{G m M_e}{r^2}$$

Where M_e is the mass of the Earth and r is the distance of the body from the centre of the Earth.

The weight of a body is due to the gravitational force with which Earth attracts a body. Gravitational force is a non-contact force.

Example

The velocity of a body, thrown up, goes on decreasing while on returns its velocity goes on increasing. This is due to the gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not. Such a force is called the field force. It is assumed that a gravitational field exists all around the Earth. This field is directed towards the centre of the Earth. The gravitational field becomes weaker and weaker as we go farther and farther away from the Earth.

Figure 5.3: Gravitational field around the Earth is towards its centre.

Gravitational Field Strength

In the gravitational field of the Earth, the gravitational force per unit mass is called gravitational field strength of the Earth. At any place its value is equal to the value of g at that point. Near the surface of the Earth, the gravitational field strength is 10 Nkg^{-1}.

Q.3 Determine the mass of the earth by using Newton's law of gravitation. **(GRW 2014, LHR 2015)**

Ans: Suppose a body of mass m is placed on the surface of the Earth. Let mass of the Earth is Me and radius of Earth be R. The distance between the body and centre of the Earth is equal to the radius of the Earth R.

According to the law of gravitation, the gravitational force F of the Earth acting on the body is given by,

$$F = \frac{G M_e m}{R^2} \quad \ldots\ldots\ldots (1)$$

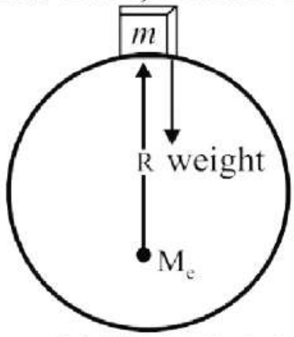


Figure 5.4: Weight of a body i Equal to the gravitational forc between the body and the Earth

We know that the force of gravitation with which Earth attracts the body towards its centre is equal to the weight of the body. Therefore,

Therefore, $F = w = mg$

OR $$mg = \frac{G M_e m}{R^2}$$

Or $$g = \frac{G Me}{R^2} \quad \ldots\ldots\ldots (2)$$

Or $$M_e = \frac{g R^2}{G} \quad \ldots\ldots\ldots (3)$$

As we know that,

$g = 10\ ms^{-2}$

$R = 6.4 \times 10^6$ m

And $G = 6.673 \times 10^{-11}\ Nm^2kg^{-2}$

By putting the value of g, R and G in equation (3), we have

$$M = \frac{gR^2}{G} = \frac{10 \times (6.4 \times 10^6)^2}{6.673 \times 10^{-11}}$$

$$M = \frac{10 \times 40.96 \times 10^{12}}{6.673 \times 10^{-11}}$$

$$M = \frac{409.6 \times 10^{12}}{6.673 \times 10^{-11}}$$

$$M = 61.4 \times 10^{23}$$

$$M = 6.14 \times 10^{24} \text{ kg}$$

$$M = 6 \times 10^{24} \text{ kg}$$

Hence the mass of the earth is approximately **6×10^{24} kg**.

Q.4 Explain the variation of 'g' with altitude. **(GRW 2015)**

Ans: As we know that

$$g = \frac{G\,Me}{R^2}$$

The above equation show that the acceleration due to gravity depends on the radius of Earth at its surface. The value of g is inversely proportional to the square of the radius of the Earth. It does not remain constant. It decreases with altitude. Altitude is the height of an object or place above sea level. The value of g is greater at sea level than at the hills.

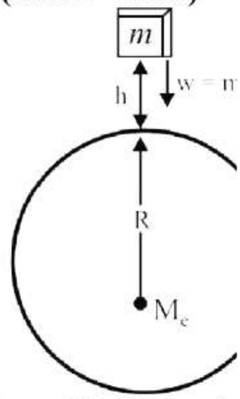


Figure 5.5: Weight of decreases as its height in from the surface of the E

Mathematical Form

Suppose a body of mass m at an altitude h. The distance of the body from the centre of the Earth is R+h. By using above equation, we have

$$g_h = \frac{GM}{(R+h)^2}$$

According to the above equation, we come to know that at a height equal to one Earth radius above the surface of the Earth, g becomes one fourth of its value on the Earth. Similarly, at a distance of two Earth's radius above the Earth's surface, the value of g becomes one ninth of its value on the Earth.

Q.5 What are artificial satellites? Define orbital velocities and what do you know about communication satellites? **(LHR 2013)**

Ans: An object that revolves around a planet is called a satellite.

Orbital Velocity

It is the velocity of the satellite with which it moves around the earth at specific height.

Natural satellite of Earth

The moon revolves around the Earth so moon is the natural satellite of Earth.

Artificial satellites

Scientists have sent many objects into space. Some of these revolve around the Earth. These are called artificial satellites.

Most of the artificial satellites orbiting around the Earth are used for communication purposes. Artificial satellites carry instruments or passengers to perform experiments in the space.

Large numbers of artificial satellites have been launched in different orbits around the Earth. They take different time to complete their one revolution around the Earth depending upon their distance h from the Earth.

Communication Satellites

Communication satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes one rotation about its axis in 24 hours, hence, these communication satellites appear to be stationary with respect to Earth. It is due to this reason that the orbit of such satellites is called geostationary orbit. Dish antennas sending and receiving the signals from them have fixed direction depending upon their location on the Earth.

Q.6 Explain the motion of an artificial satellite and derive the formula for orbital velocity of an artificial satellite. **(LHR 2013, 2014, 2015, GRW 2014)**

Ans: A satellite requires centripetal force that keeps it to move around the Earth. The gravitational force of attraction between the satellite and the Earth provides the necessary centripetal force.

Figure 5.6: A satellite is orbiting around the Earth at a height *h* above the surface of the Earth.

Mathematical Derivation

Suppose a satellite of mass m is revolving around the Earth at a height 'h' in an orbit of radius r_o with orbital velocity v_o. The necessary centripetal force F_c required to keep the satellite moving is given by,

$$F_c = \frac{mv_o^2}{r_o} \quad \ldots\ldots (1)$$

This centripetal force is provided to the satellite by the gravitational force of attraction between the Earth and satellite and is equal to the weight of the satellite w (mg_h). thus

$$F_c = w = mg_h \quad \ldots\ldots (2)$$

By comparing equation (1) and equation (2), we get

Or $$mg_h = \frac{mv_o^2}{r_o}$$

Or $$v_o^2 = g_h r_o$$

Or $$v_o = \sqrt{g_h r_o}$$

As $$r_o = R + h$$

So $$v_o = \sqrt{g_h (R + h)} \quad \ldots\ldots (3)$$

This equation represents the orbital velocity, which a satellite must possess when launched in an orbit of radius $r_o = R + h$ around the Earth. An approximation can be made for a satellite revolving close to the Earth such that $R >> h$.

$R + h \approx R$

And $g_h \approx g$

So $v_o = \sqrt{g R}$

A Satellite revolving around very close to the Earth has speed nearly 8 kms^{-1} or 29000 kmh^{-1}.

Unit 5: Gravitation

Multiple Choice Questions

1. **---------- predicted about artificial satellites about 300 years ago.**
   (a) Galileo **(b)** Newton
   (c) Einstein **(d)** Faraday
2. **Unit of gravitational field strength is:**
   (a) N **(b)** N kg^{-1}
   (c) J **(d)** N m
3. **Distance of moon from Earth is?** **(GRW 2013, 2014)**
   (a) 38, 000 km **(b)** 3, 80, 000 km
   (c) 3, 000, 000 km **(d)** 30, 000 km
4. **Speed of GPS satellite is:**
   (a) 7.9 kms^{-1} **(b)** 3.87 kms^{-1}
   (c) 5.6 kms^{-1} **(d)** 5.0 kms^{-1}
5. **If the distance between two masses is half then the force of gravitation becomes:**
   (a) One fourth **(b)** Four times
   (c) Doubled **(d)** Half
6. **In System International, the value of G is:** **(GRW 2012)**
   (a) 6.4×10^{6} Nm^2kg^{-2} **(b)** 6.4×10^{-11} Nm^2kg^{-2}
   (c) 6.67×10^{11} Nm^2kg^{-2} **(d)** 6.67×10^{-11} Nm^2kg^{-2}
7. **Radius of earth is:**
   (a) 6.4×10^{6} km **(b)** 6.4×10^{6} m
   (c) 6×10^{6} m **(d)** 6×10^{6} km
8. **The SI unit of gravitational force is:**
   (a) Nm^2kg^{-2} **(b)** Newton
   (c) ms^{-2} **(d)** both "a" and "b"
9. **What will be the value of G if mass of the earth becomes four times:**
   (a) No change **(b)** Four times
   (c) One fourth **(d)** Doubled
10. **The mass of Earth is approximately:**
    (a) 6.9×10^{24} kg **(b)** 6.0×10^{-24} kg
    (c) 6.0×10^{24} kg **(d)** 5500×10^{24} kg
11. **As we go up the value of G becomes:**
    (a) Unchanged **(b)** Increases
    (c) Decreases **(d)** Doubled
12. **The force which pulls the object towards the center of circle is known as --------- force:**
    (a) Frictional **(b)** Coulomb
    (c) Centripetal **(d)** Gravitational
13. **When an object is at a height equal to radius of earth above the surface of the earth. What is the value of g_h?** **(LHR 2013)**
    (a) 4g **(b)** 2g
    (c) g/2 **(d)** g/4
14. **What is not true about g?**
    (a) g is different at different places **(b)** g is greater at poles
    (c) g is less at poles **(d)** g decrease as go higher

15. **If the weight of an object on the surface of earth is W. Its weight on the surface of moon will be:**

(a) 6W **(b)** W/6
(c) W/4 **(d)** W/8

16. **On mountains our weight will be ---------- as compared to weight on the surface of earth.**

(a) Equal **(b)** Greater
(c) Less **(d)** None of above

17. **If mass of both the bodies is 1kg and distance between their centers is 1m then the gravitational force will be equal to:**

(a) G **(b)** g
(c) V **(d)** None of above

18. **A satellite is revolving around the earth in a circular orbit. If the radius of the orbit is increased from R to 2R. What will be its velocity?**

(a) $\sqrt{2}v$ **(b)** v^2
(c) v/2 **(d)** $\frac{v}{\sqrt{2}}$

19. **An artificial satellite keeps on revolving around the earth in different orbits with uniform speed due to the?**

(a) Gravitational force **(b)** Frictional force
(c) Coulmb force **(d)** Electromagnetic force

20. **Relative velocity of Geostationary satellite with respect to earth is:**

(a) 7.9 kms^{-1} **(b)** 11.2 kms^{-1}
(c) 9.8 ms^{-1} **(d)** Zero

21. **If a rocket is fired vertically with a speed of -----------, it will start revolving around the earth:** **(GRW 2013, LHR 2015)**

(a) 8 ms^{-1} **(b)** 8 kms^{-1}
(c) 9.8 ms^{-1} **(d)** 11.2 kms^{-1}

22. **Height of the Geostationary satellite above the surface of earth is:**

(a) 1000 km **(b)** 3600 km
(c) 36000 km **(d)** 42300 km

23. **Gravitational force on the surface of earth is equal to:**

(a) G **(b)** g
(c) W **(d)** All of above

24. **Weight of the body of mass 10 kg on the surface of moon:** **(LHR 2016)**

(a) 160 N **(b)** 16N
(c) 1.62 N **(d)** None of above

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans
1	b	11	a	21	b
2	b	12	c	22	d
3	b	13	d	23	c
4	b	14	c	24	b

5	b	15	b	
6	d	16	c	
7	b	17	a	
8	b	18	a	
9	a	19	a	
10	c	20	d	

Unit 5: Gravitation

Problems

5.1 Find the gravitational force of attraction between two spheres each of mass 1000 kg. The distance between the centers of the spheres is 0.5m.

Given Data

Mass of each sphere = $m_1 = m_2 = 1000$ kg

Distance between their centers = d = 0.5 m

Required

Gravitational force between the spheres = F = ?

Solution

From the law of gravitation, we have

$$F = \frac{G\, m_1 m_2}{d^2}$$

By putting the values, we have

$$F = \frac{6.67 \times 10^{-11} \times 1000 \times 1000}{(0.5)^2}$$

$$F = \frac{6.67 \times 10^{-5}}{0.25}$$

$$F = 26.68 \times 10^{-5}$$

$$F = 2.67 \times 10^{-4} \text{ N}$$

Result

Gravitational force between the spheres = F = 2.67×10^{-4} N

5.2 The gravitational force between two identical lead spheres kept at 1 m apart is 0.006673 N. Find their masses.

Given Data

Gravitational force = F = 0.006673 N

Distance between centers = r = 1 m

Gravitational constant = 6.67×10^{-11} Nm^2kg^{-2}

Required

Mass of each lead spheres = $m_1 = m_2$ = ?

Solution

From law of gravitation, we have

$$F = G\,\frac{m_1 \times m_2}{r^2}$$

OR $\quad m_1 \times m_2 = \frac{F \times r^2}{G}$

By putting the values, we have

$$m_1 \times m_2 = \frac{0.006673 \times (1)^2}{6.67 \times 10^{-11}}$$

$m_1 \times m_2 = 0.001000 \times 10^{11}$

$m_1 \times m_2 = 1.00 \times 10^8$

As $\quad m_1 = m_2$

So $\quad m_1^2 = 1.00 \times 10^8$

$m_1 = 1.00 \times 10^4$ kg

So $\quad m_2 = 1.00 \times 10^4$ kg

Result

Mass of each lead spheres = $m_1 = m_2 = 1 \times 10^4$ kg

5.3 Find the acceleration due to gravity on the surface of the Mars. The mass of Mars is 6.42×10^{23} kg and its radius is 3370 km.

Given Data

Mass of the mars = M = 6.42×10^{23} kg

Radius of mars = R = 3370 km = 3370×10^3 m = 3.37×10^6 m

Required

Gravitational acceleration = g = ?

Solution

As we know that

$$g = \frac{GM}{R^2}$$

by putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}{(3.77 \times 10^6)^2}$$

$$g = \frac{42.8214 \times 10^{12}}{11.3569 \times 10^{12}}$$

$$g = 3.77 \text{ ms}^{-2}$$

Result

Gravitational acceleration = g = 3.77 ms^{-2}

5.4 The acceleration due to gravity on the surface of moon is 1.62 ms^{-2}. The radius of Moon is 1740 km. Find the mass of moon.

Given Data

Gravitational acceleration on Moon = g_m = 1.62 ms^{-2}

Radius of moon = R_m = 1740 km = 1740×10^3 m = 1.74×10^6 m

Gravitational constant = G = 6.67×10^{-11} N m^2 kg^{-2}

Required

Mass of the moon = M = ?

Solution

As we know that

$$M = \frac{gR^2}{G}$$

by putting the values, we have

$$M = \frac{1.62 \times (1.74 \times 10^6)^2}{6.67 \times 10^{-11}}$$

$$M = \frac{1.62 \times 3.0276 \times 10^{12}}{6.67 \times 10^{-11}}$$

$$M = \frac{4.90 \times 10^{12}}{6.67 \times 10^{-11}}$$

$M = 0.735 \times 10^{23}$

$M = 7.35 \times 10^{22}$ kg

Result

Mass of the moon = M = 7.35×10^{22} kg

5.5 Calculate the value of *g* at a height of 3600 km above the surface of the Earth.

Given Data

Height above the surface of Earth = h = 3600 km = $3600 \times 10^3 = 3.6 \times 10^6$ m

Gravitational constant = G = 6.67×10^{-11} N m^2 kg^{-2}

Mass of Earth = M = 6×10^{24} kg

Required

Gravitational acceleration = g = ?

Solution

As we know that

$$g = \frac{GM}{(R+h)^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6 + 3.6 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{(10 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{1 \times 10^{14}}$$

$g = 40.02 \times 10^{-1}$

$g = 4.002$ ms^{-2}

$g = 4.0$ ms^{-2}

Result

Gravitational acceleration = g = 4 ms^{-2}

5.6 Find the value of *g* due to the Earth at geostationary satellite. The radius of the geostationary orbit is 48700 km.

Given Data

Radius of geostationary satellite = R =48700 km=48700×10^3 m=4.87×10^7 m

Mass of earth = M = 6×10^{24} kg

Gravitational constant = R = 6.67×10^{-11} N m^2 kg^{-2}

Required

Gravitational acceleration = g_h = ?

Solution

As we know that

$$g = \frac{GM}{(R+h)^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(4.87 \times 10^{7})^2}$$

$$g = \frac{40.02 \times 10^{13}}{23.72 \times 10^{14}}$$

$$g = 1.68 \times 10^{-1}$$

$$g = 0.168\ ms^{-2}$$

$$g = 0.17\ ms^{-2}$$

Result

Gravitational acceleration = g_h = 0.17 ms^{-2}

5.7 The value of *g* is 4.0 ms^{-2} at a distance of 10000 km from the centre of the Earth. Find the mass of the Earth.

Given Data

Gravitational acceleration = g_h = 4.0 ms^{-2}
Distance from centre of Earth = R+ h = 10000 km = 10000 km = 1×10^7 m
Gravitational constant = G = 6.67×10^{-11} N m^2 kg^{-2}

Required

Mass of earth = M = ?

Solution

As we know that

$$g_h = \frac{GM_e}{(R+h)^2}$$

By putting the values, we have

$$M_e = \frac{g_h (R+h)^2}{G}$$

$$M_e = \frac{4 \times (1.0 \times 10^{7})^2}{6.67 \times 10^{-11}}$$

$$M_e = \frac{4 \times 10^{14}}{6.67 \times 10^{-11}}$$

$$M = 0.599 \times 10^{25}$$

$$M_e = 5.99 \times 10^{24}$$

$$M_e = 6 \times 10^{24}\ kg$$

Result

Mass of Earth = M_e = 6 x 10^{24} kg

5.8 At what altitude the value of *g* would become one fourth than on the surface of the Earth?

Given Data

Gravitational acceleration = g = 10 m^{-2}

Gravitational acceleration at height = $g_h = \frac{g}{4} = \frac{10}{4} = 0.25\ ms^{-2}$

Gravitational constant = G = 6.67 x $10^{-11}\ Nm^2kg^{-2}$

Mass of earth = M = 6 x 10^{24} kg

Required

Height of the satellite = h = ?

Solution

As we know that

$$g_h = \frac{GM_e}{(R+h)^2}$$

$$\frac{g}{4} = \frac{GM_e}{(R+h)^2}$$

Again we know that

$$M_e = \frac{gR^2}{G}$$

or $GM_e = gR^2$

Putting he value of GM_e in eq-------(1)

$$\frac{g}{4} = \frac{gR^2}{(R+h)^2}$$

or $$\frac{1}{4} = \frac{R^2}{(R+h)^2}$$

or $$(R+h)^2 = 4R^2$$

Taking square root on both sides

$$\sqrt{(R+h)^2} = \sqrt{4R^2}$$

R+h = 2R

h = 2R – R

h = R

Result

Required altitude is equal to one earth's radius.

5.9 A polar satellite in launched at 850 km above Earth. Find its orbital speed. (LHR 2014)

Given data:

Hight of satellite = h = 850 km

= 850 × 1000

= 8.5 × 10^5m

Mass of earth = Me = 6× 10^{24} kg

Gravitational constant = G = 6.673 × 10^{-11} $Nm^2\ kg^{-2}$

Required:

Orbital speed of satellite = V_o = ?

Solution:

We know that

$$V_o\sqrt{g_h(R+h)}$$

Putting the value of g_h

$$V_o=\sqrt{\frac{GM_e}{(R+h)^2}(R+h)}$$

$$V_o=\sqrt{\frac{GM_e}{R+h}}$$

$$=\sqrt{\frac{(6.673\times10^{-11})(6\times10^{24})}{6.4\times10^{6}+8.5\times10^{5}}}$$

$$=\sqrt{\frac{4.0038\times10^{14}}{7250000}}$$

$$V_o=\sqrt{55224827.59}$$

$$V_o=7431\,\text{ms}^{-1}$$

Result:

Orbital speed of satellite = V_o = 7431 ms^{-1}

5.10 A communication satellite is launched at 42000 km above Earth. Find its orbital speed.

Given Data

Height of satellite = h = 42000 km = 42000 x 10^3 m = 4.2 x 10^7 m

Mass of earth = M = 6 x 10^{24} kg

Gravitational constant = G = 6.673 x 10^{-11} Nm^2kg^{-2}

Required

Orbital speed of satellite = V_o = ?

Solution

As we know that

$$v_o=\sqrt{g_h(R+h)}$$

Putting the value of g_h

$$V_o=\sqrt{\frac{GM_e}{(R+h)^2}(R+h)}$$

$$V_o=\sqrt{\frac{GM_e}{(R+h)}}$$

By putting the values, we have

$$v_o=\sqrt{\frac{(6.673\times10^{-11})(6\times10^{24})}{6.4\times10^{6}+4.2\times10^{7}}}$$

$$v_o=\sqrt{\frac{4.0038\times10^{14}}{48400000}}$$

$$v_o=\sqrt{8272314.05}$$

$$v_o = 2876\ ms^{-1}$$

Result

Orbital speed of satellite = v_o = 2876 ms^{-1}

Unit 6: Work and Energy

Textbook Exercise Questions

6.1 Encircle the correct answer from the given choices.

i. The work done will be zero when the angle between force and distance is: (GRW 2014)

(a) 45^o (b) 60^o
(c) 90^o ✓ (d) 180^o

ii. If the direction of motion of the force is perpendicular to the direction of motion of the body, then work done will be:

(a) Maximum (b) minimum
(c) zero ✓ (d) none of above

iii. If the velocity of a body becomes double, then its kinetic energy will:

(a) Remains the same (b) becomes double
(c) becomes four times ✓ (d) become half

iv. The work done in lifting a brick of mass 2 kg through a height of 5 m above the ground will be: (LHR 2014)

(a) 2.5 J (b) 10 J
(c) 50 J **(d) 100 J ✓**

v. The kinetic energy of a body of mass 2 kg is 25 J. Its speed is:

(a) $5\ ms^{-1}$ ✓ (b) $1.5\ ms^{-1}$
(c) $12.5\ ms^{-1}$ (d) $50\ ms^{-1}$

vi. Which one of the following converts light energy into electrical energy? (LHR 2014)

(a) Electric bulb (b) electrical generator
(c) photocell ✓ (d) electric cell

vii. When a body is lifted through a height 'h', the work done on it appears in the form of its:

(a) kinetic energy **(b) potential energy ✓**
(c) elastic potential energy (d) geothermal energy

viii. The energy stored in coal is: (GRW 2013)

(a) heat energy (b) kinetic energy
(c) chemical energy ✓ (d) nuclear energy

ix. The energy stored in a dam is: (GRW 2015)

(a) electrical energy **(b) potential energy ✓**
(c) kinetic energy (d) thermal energy

x. In Einstein's mass-energy equation, c is the (LHR 2015)

(a) speed of sound **(b) speed of light ✓**
(c) speed of electron (d) speed of Earth

xi. Rate of doing work is called

(a) energy (b) torque
(c) power ✓ (d)momentum

6.2 Define work. What is its SI unit? **(LHR 2014)**

Ans: Work is done when force acting on a body displaces it in the direction of a force.

Unit of work

In System International, its unit is joule (J).

Joule

The amount of Work done will be one joule if a force of one Newton displaces a body through a distance of one meter in the direction of the force.

6.3 When does a force do work? Explain.

Ans: When force acts on the body and body covers some distance in the direction of force then we said work is done. And this work can be calculated by the formula.

$W = F \times S$

6.4 Why do we need energy?

Ans: We need energy to do different types of work in our daily life. When we say that body has energy, we mean that it has the ability to do work.

Examples

- Energy is required to move.
- Energy is required to stop the moving objects.

6.5 Define energy; give two types of mechanical energy.

Ans: A body possesses energy if it is capable to do work.

OR

Ability of a body to do work is known as energy.

Types of Mechanical Energy

Mechanical energy possessed by a body is of two types:

i) Kinetic Energy

ii) Potential Energy

6.6 Define K.E. and derive its relation.

Ans: See Q. no.2 Long Question

6.7 Define potential energy and drive its relation. **(LHR 2013)**

Ans: See Q. no.3 Long Question

6.8 Why fossils fuels are called non - renewable form energy? **(LHR 2013)**

Ans: Fossil fuels took millions of years for their formation and once they are consumed, they cannot be generated again so they are called non-renewable form of energy.

6.9 Which form of energy is most preferred and why?

Ans: Solar energy is most preferred because it is the ultimate source of energy for life and sunrays do not pollute the environment. It is huge source of energy and if we find a suitable method to use a fraction of the solar energy reaching the Earth, then it would be enough to fulfill our energy requirements.

6.10 How is energy converted from one form to another? Explain.

Ans: See Q. no.5 Long Question

6.11 Name the five devices that convert electrical energy into mechanical energy.

Ans

(i) Electric Motor
(ii) Electric Fan
(iii) Elevator
(iv) Drill machine
(v) Grinder
(vi) Sewing machine

6.12 Name a device that converts mechanical energy into electrical energy. (LHR 2016)

Ans: Electric Generator is device which is used to convert the mechanical energy into electrical energy.

6.13 What is meant by efficiency of a system?

Ans: Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

Example

Electric motors may be used to pump water, to blow air, to wash clothes, to drill holes, etc. for that they use electric energy. How good a machine is, depends how much output we obtain from it by giving certain input. The ratio of useful output to input energy is very important to judge the working of machine.

6.14 How can you find the efficiency of a system?

Ans: Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

Mathematically, it can be calculated as:

$$\text{Efficiency} = \frac{\text{Required form of output}}{\text{Total input energy}}$$

Or

$$\%\ \text{Efficiency} = \frac{\text{Required form of output}}{\text{Total input energy}} \times 100$$

6.15 What is meant by the term power? (GRW 2013, LHR 2012, 2016)

Ans: "Rate of doing work with respect to time is called the power."

Thus

$$\text{Power} = \frac{\text{Work}}{\text{time}}$$

If we represent power by 'P', work by 'W' and time by 't', then

$$P = \frac{W}{t}$$

6.16 Define watt. (LHR 2011, 2014, 2016)

Ans: In System International, the unit of power is watt (W).

Watt

If a body does a work of one joule in one second then its power will be one watt.

$1\ W = 1\ Js^{-1}$

Bigger Units

$1\ KW = 10^3\ W$

$1\ MW = 10^6\ W$

Unit 6: Work and Energy

Long Questions

6.1 WORK

Q.No.1 Define work. Derive its mathematical formula.

Ans: Definition

Work is done when force acting on a body displaces it in the direction of a force.

OR

The product of force and distance covered in the direction of force is equal to the work done.

Explanation

Suppose a force 'F' is acting on a body. It makes the body to move from point 'A' to 'B'. If the distance between these two points is 'S' then we say that force has done some work.

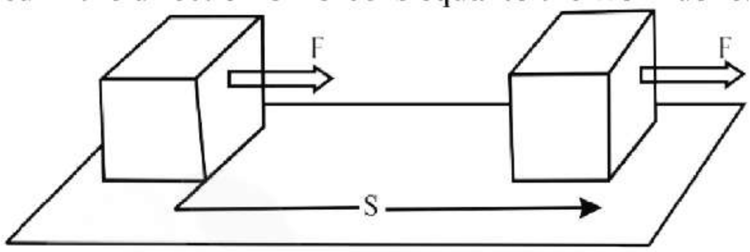


Figure 6.1: Work done in displacing a body in the direction of force.

Conditions

For work, the following two conditions must be fulfilled:

- A force should act on a body.
- The body should cover some distance under the action of this force.

Mathematical Form

If 'W' stands for work, 'F' for force and 'S' for distance.

then

Work = Force x Displacement

W = FS

Components of Force

Sometimes force and displacement do not have same direction. Here the force **F** is making an angle θ with the surface on which the body is moved. Resolving **F** into its perpendicular components 'F_x' and 'F_y'.

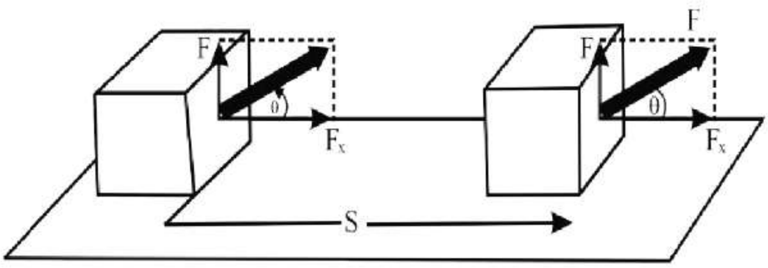


Figure 6.2: Work done by a force inclined with the displacement.

$F_x = F \cos \theta$

$F_y = F \sin \theta$

In case when force and displacement are not parallel then x-component F_x parallel to the surface causes the body to move on the surface and not y-component F_y.

Hence $W = F_x S$

$W = (F\cos \theta) S$

$W = FS \cos \theta$

Work is a scalar quantity. It depends on the force acting on a body, displacement of the body and the angle between them

Unit of work

In System International, its unit is joule (J).

Joule

"The amount of Work done will be one joule if a force of one Newton displaces a body through a distance of one meter in the direction of the force."

Bigger Units

Joule is a smaller unit of work. Commonly bigger units of work are also in use.

$1\ kJ = 10^3 J$

$1\ MJ = 10^6 J$

6.3 KINETIC ENERGY

Q.No.2 Define kinetic energy and derive its mathematical formula. (LHR 2011, 12, GRW 2011)

Ans: "The energy possessed by a body due to its motion is called kinetic energy"

Example

- Moving air is called wind. We can use wind energy for doing various things. It drives windmills and pushes sailing boats.
- Moving water in a river can carry wooden logs through large distances and can also be used to drive turbines for generating electricity.

Mathematical Derivation

Let a body of mass m is moving with velocity v. An opposing force F acting through a distance S brings it to rest. The body possesses kinetic energy and is capable to do work against opposing force F until all of its kinetic energy used up.

K.E of the body = Work done by it due to motion

$K.E = FS$

$v_i = v$

$v_f = 0$

As $F = ma$

$a = -F/m$

Since motion is opposed, hence, a is negative.

Using 3rd equation of motion:

$2aS = v_f^2 - v_i^2$

$2(-F/m)S = (0)^2 - (v)^2$

$FS = \frac{1}{2} m v^2$

As we know that K.E is equal to the work done,

So $K.E. = \frac{1}{2} m v^2$

The above equation gives the K.E. possessed by a body of mass m moving with velocity v.

6.4 POTENTIAL ENERGY

Q.No.3 Define Gravitational Potential Energy and derive its mathematical formula.

Ans: The energy present in a body due to its height is called gravitational potential energy.

Mathematical Derivation

Suppose a ball of mass 'm' is lifted from the surface of the Earth to a height 'h' as shown in Figure. The body will acquire potential energy equal to the work done in lifting it to height h.

Thus Potential Energy $= F \times h$

$= w \times h$

As we know that weigh of the body = w = mg

So $P.E. = wh = mgh$

Thus, the potential energy possessed by the body with respect to the ground is m g h and is equal to the work done in lifting it to a height h.

6.5 FORMS OF ENERGY

Q.No.4 Explain different Forms of Energy.

Ans: Energy exists in various forms. Some of the main forms of energy are explained below:

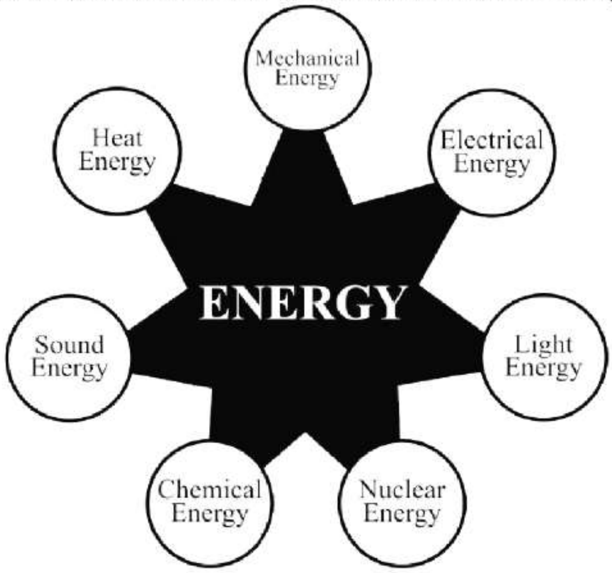


Figure 6.6: Some of the main forms of energy

1) Mechanical Energy

The energy possessed by a body due to its motion or position is called mechanical energy.

Examples

- Water running down a stream
- A moving car
- A lifted hammer
- A stretched bow
- A catapult or a compressed spring

2) Heat Energy

Heat is a form of energy given out by hot bodies. Large amount of heat is obtained by burning fuel. Heat is also produced when motion is opposed by frictional forces. The foods we take provide us heat energy. The Sun is the main source of heat energy.

3) Electrical Energy **(GRW 2015)**

Electricity is one of the widely used forms of energy. Electrical energy can be supplied easily to any desired place through wires.

Sources

We get electrical energy from batteries and electrical generators. These electric generators are run by hydro power, thermal or nuclear power.

4) Sound Energy **(GRW 2015)**

Sound is a form of energy. It is produced when a body vibrates.

Examples

Sound is produced by:

- By knocking at the door
- By vibrating diaphragm of a drum
- By vibrating strings of a sitar
- By vibrating air column of wind instruments as flute pipe

5) Light Energy

Light is an important form of energy. Plants produce food in the presence of light. We also need light to see things.

Sources

We get light from candles, electric bulbs, and fluorescent tubes and also by burning fuel. However, most of the light comes from the Sun.

6) Chemical Energy

Chemical energy is present in food, fuels and in other substances. We get other forms energy these substances during chemical reactions.

Examples

- The burning of food, coal or natural gas in air is a chemical reaction which releases energy as heat and light.
- Electric energy is obtained from electric cells and batteries as a result of chemical substances present in them.
- Animals get heat and muscular energy from the food they eat.

7) **Nuclear Energy**

Nuclear energy is the energy released in the form of nuclear radiations in addition to heat and light during nuclear reactions such as fission and fusion reactions. Heat energy released in nuclear reactors is converted into electrical energy.

Biggest source

The energy coming from the Sun for the last billions of years is the result of nuclear reactions taking place on the Sun.

6.6 INTERCONVERSION OF ENERGY

Q.No.5 Explain Inter Conversion of Energy.

Ans: Energy cannot be destroyed however it can be converted into some other forms.

Example

Rub your hands together quickly. You will feel them warm. You have used your muscular energy in rubbing hands as a result heat is produced. In the process of rubbing hands, mechanical energy is converted into heat energy.

Interconversion of energy in Nature

Processes in nature are the results of energy changes. For example, some of the heat energy form the Sun is taken up by water in the oceans. This increases the thermal energy. Thermal energy causes water to evaporate from the surface to form water vapors. These vapors rise and form clouds. As they cool down, they form water drops and fall down as rain. Potential energy changes to kinetic energy as the rain falls. This rain water may reach a lake or a dam. As the rain water flows down, its kinetic energy changes into thermal energy while parts of the kinetic energy flowing water is used to wash away soil particles of rocks known as soil erosion.

Total Energy

During the inter conversion of energy from one form to other forms, the total energy at any time remains constant.

6.7 MAJOR SOURCES OF ENERGY

Q.No.6 Explain Major Sources of Energy.

Ans: The energy we use comes from the Sun, wind and water power etc. Actually, all of the energy we get comes directly or indirectly from the Sun.

1) **Fossil Fuels**

We use fossil fuels such as coal, oil and gas to heat our houses and run industry and transport. They are usually hydrocarbons (compounds of carbon and hydrogen).

Chemical Reaction

When they are burnt, they combine with oxygen from air. The carbon becomes carbon dioxide; hydrogen becomes hydrogen oxide called water; while energy is released as heat. In case of coal;

Carbon + Oxygen $\longrightarrow$ carbon dioxide + heat energy

Hydrocarbon + Oxygen $\longrightarrow$ carbon dioxide + water + heat energy

Future of Hydrocarbons

The fossil fuels took millions of years for their formation. They are known as non-renewable resources. We are using fossil fuels at a very fast rate. Their use is increasing day by day to meet them at present rate, they will soon be exhausted. Once their supply is exhausted, the world would face serious energy crises.

Future Crises of Energy

Thus, fossil fuels would not be able to meet our future energy needs. This would cause serious social and economical problems for countries like us. Therefore, we must use them wisely and at the same time, develop new energy sources for our future survival.

Harmful effects produced by burning Hydrocarbons

Moreover, fossil fuels release harmful waste products. These wastes include carbon mono-oxide and other harmful gases, which pollute environment. This causes serious health problems such as headache, tension, nausea, allergic reactions, and irritation of eyes, nose and throat. Long exposure of these harmful gases may cause asthma, lungs cancer, heart diseases and even damage to brain, nerves and other organs of our body.

2) Nuclear Fuels

In nuclear power plants, we get energy as a result of fission reactions. During fission reaction, heavy atoms, such as uranium atoms, split up into smaller parts releasing a large amount of energy. Nuclear power plants give out a lot of nuclear radiations and vast amount of heat. A part of this heat is used to run power plants while lot of heat goes waste into the environment.

Renewable Energy Sources

Q.No.7 Explain Renewable Energy Sources.

Ans: Sources of energy which will not be run out in future are called Renewable sources. Sunlight and water power are the renewable sources of energy.

1) Energy Form Water

Energy from water power is very cheap. Dams are being constructed at suitable locations in different parts of the world. Dams serve many purposes. They help to control floods by storing water. The water stored in dams is used for irrigation and also to generate electric energy without creating much environmental problems.

2) Energy from Sun

Solar energy is the energy coming from the sun and is used directly and indirectly. Sunlight does not pollute the environment in any way. The sunrays are the ultimate source of life on the Earth. We are dependent on the Sun for all our food and fuels. If we find a suitable method on use a fraction of the solar energy reaching the Earth, then it would be enough to fulfill our energy requirements.

Q.No.8 Explain Solar House Heating. (LHR 2014)

Ans: The use of solar energy is not new. However, it's use in houses and offices as well as for commercial industrial purposes is quite recent. Complete solar house heating system are successfully used in area with a minimum amount of sunshine in winter. A house heating system consists of:

- A collector
- A storage device
- A distribution system

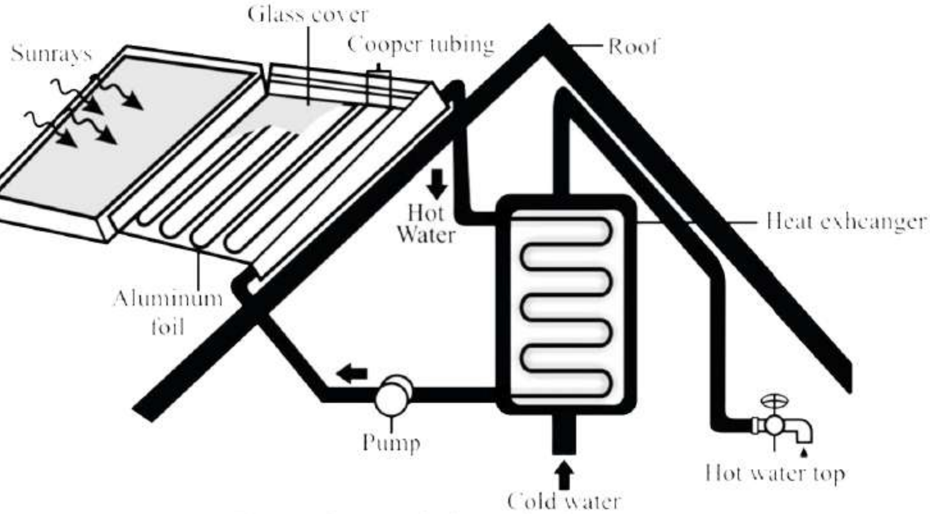


Figure 6.21: A Solar house heating system.

The above figure shows a solar collector made of glass panels over blank metal plates. The plates absorb the sun energy which heats a liquid flowing in the pipes at the back of the collector. The hot water can be used for cooking, washing and heating the buildings.

Solar energy is used in solar cookers, solar distillation plants, solar power plants.

Solar cells

Solar energy can also be converted directly into electricity by solar cells. A solar cell also called photo cell is made from silicon wafer. When sunlight falls on the solar cell, it converts the light directly into electrical energy.

Solar panels

Solar cells are used in calculators, watches and toys. Large number of solar cells are wired together to form a solar panel. Solar panels can provide power to telephone booths, light houses and scientific research centers. Solar panels are also used to power satellites.

Q.No.9 What are the future hopes of the world about energy?

Ans: Solar Energy

Several other methods to trap sunrays are under way. If scientist could find an efficient and in-expansive method to use solar energy, then the people could get clean, limitless energy as long as the Sun continues to shine.

Wind Energy

Wind has been used as a source of energy for centuries. It has powered sailing ships across the oceans. It has been used by wind mills to grind grain and pump water.

Wind Turbines

More recently, wind power is used to turn wind turbines. When many wind machines are grouped together on wind farms, they can generate enough power to operate a power plant. In the United States, some wind farms generate more than 1300 MW of electricity a day. In Europe, many wind farms routinely generate hundred megawatts or more electricity a day.

Geothermal Energy

In some parts of the world, the earth provides us hot water from geysers and hot springs. There is hot molten part, deep in the Earth called magma. Water reaching close to the magma changes to steam due to high temperature of magma. This energy is called geothermal energy.

Geothermal well

Geothermal well can be built by drilling deep near hot rocks at places, where magma is not very deep. Water is then pushed into the well. The rocks quickly heat the water and change it into steam. It expands and moves up to the surface. The steam can be pipes directly into houses and offices for heating purposes or it can be used to generate electricity.

Energy from Biomass **(GRW 2015)**

Biomass is plant or wastes that can be burnt as fuel. Other forms of biomass are garbage, farm wastes, sugarcane and other plants. These wastes are used to run power plants. Many industries that use of forest products get half of their electricity by burning bark and other wood wastes. Biomass can serve as another energy source, but problems are there in its use.

Source of biomass

When animal dung, dead plants are dead animals decompose, they give off a mixture of methane and carbon dioxide. Electricity can be generated by burning methane.

Mass Energy Equation

Q.No.10 Explain Mass – Energy Equation. **(GRW 2015)**

Ans: Einstein predicted the Interconversion of matter and energy. According to him, a loss in the mass of a body provides us a lot of energy. This happens in nuclear reactions.

Equation

The relation between mass m and energy E is given by Einstein mass – energy equation.

$$E = m c^2$$

Here c is the speed of light ($3 \times 108\ ms^{-1}$). The above equation shows that tremendous amount of energy can be obtained from small quantity of matter. It appears that matter is highly concentrated form of energy.

Energy on Sun and Stars

This process of getting energy from our nuclear power plants is taking place on the sun and stars for the last millions of years. Only a very small fraction of the sun energy reaches the earth. This very small fraction of the sun energy is responsible for life on the earth.

Electricity from Fossil Fuels

Q.No.11 Explain the electricity from fossil fuels with block diagram.

Ans: We are using electricity in houses, offices, schools, business centers, factories and in farms. We have different ways of generating electricity. Most of the electricity is obtained using fossil fuels such as oil, gas and coal. Fossil fuels are burnt in thermal power stations to produce electricity. Various energy conversion process involved in producing electricity from coal are described in block diagram.

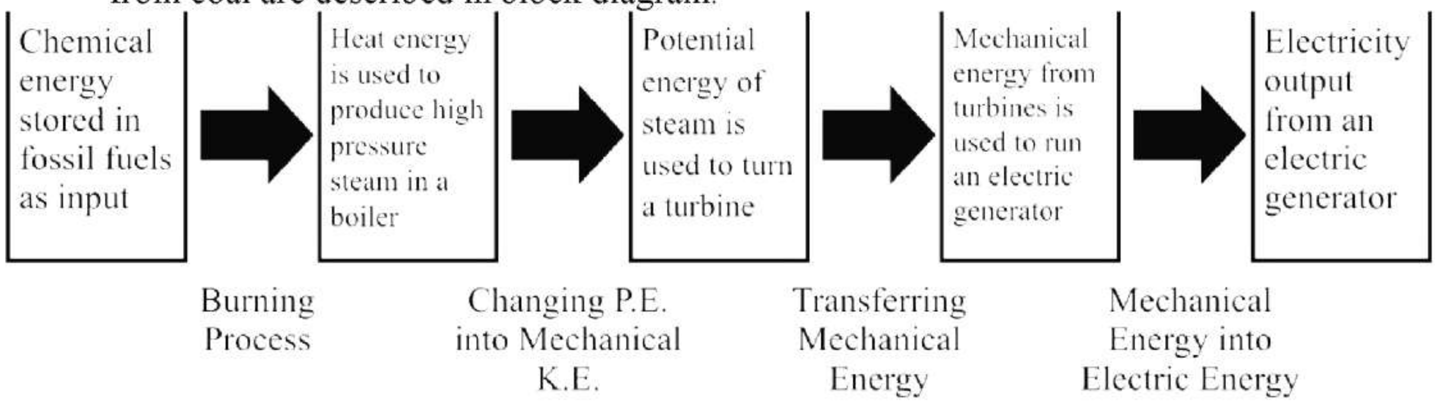


Figure 6.27: Several energy conversion processes are involved in producing electricity.

Q.No.12 Explain the effect of consumption of Energy on Environment.

Ans: Environmental problems such as pollution that consists of noise, air pollution and water pollution may arise by using different sources of energy such as fossil fuels and nuclear energy.

Pollution

Pollution is the change in the quality of environment. Pollution is the changes unpleasant for living things.

Thermal pollution

A temperature rise in the environment that disturbs life is called thermal pollution. Thermal pollution upsets the balance of life and endangers the survival of many species.

Air pollution

Air pollutions are unwanted and harmful. Natural processes such as volcanic eruptions, forest fires and dust storms add pollutant to the air. These pollutant, rarely build up to harmful levels. On the other hand, the burning of fuel and solid wastes in homes automobiles, and factories releases harmful amount of air pollutants.

Nuclear pollution

All power plants produce waste heat, but fission plants produce the most. The heat released into a lake, a river or an ocean upsets the balance of life in them. Unlike other power plants, nuclear power plants do not produce carbon dioxide. But they produce dangerous radioactive waste.

Government Laws

In many countries, governments have passes laws to control air pollution. Some of these laws limit the amount of pollution level that, power plants, factories and automobiles are allowed to give off. To meet these conditions for automobiles, new cars have catalytic gases. The use of lead free petrol has greatly reduced the amount of lead in air. Engineers are working to improve new kinds of cars that use electricity or energy sources other than petrol and diesel.

Individual Efforts

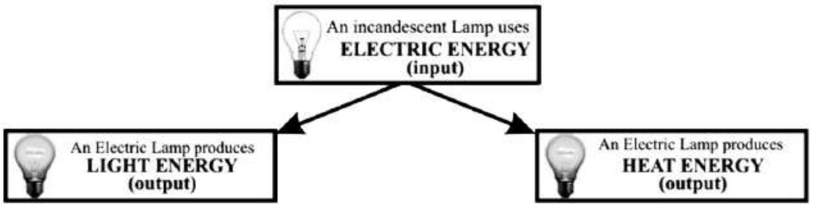
Many individual communities have laws which protect their areas from pollution. Individuals can help to control air pollutions simply by reducing the use of cars and other machines that burnt fuel. Sharing rides and using public transportation are the ways to reduce the number of automobiles in use.

Flow Diagram of an Energy Converter

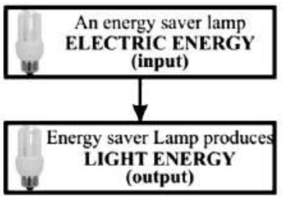
Q.No.13 Draw the Flow Diagram Of An Energy Converter. **(GRW 2015)**

Ans: In an energy converter, a part of energy taken (used up) by the system is converted into useful work. Remaining part of the energy is dissipated as heat energy, sound energy (noise) into the environment. Energy flow diagram given below shows the energy taken up by an energy converter to transform it into other forms of energy.

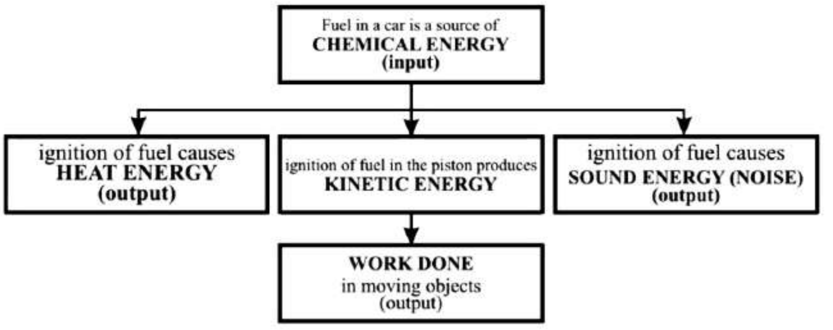
ELECTRIC LAMP



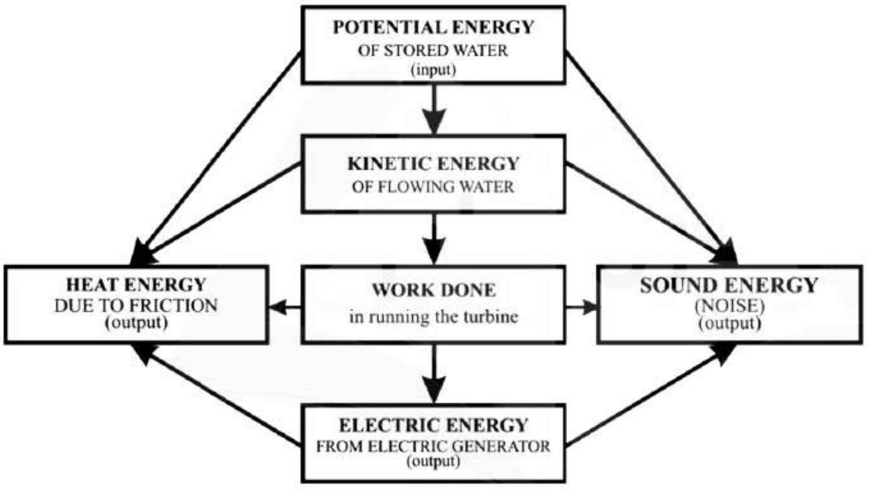
ENERGY SAVER LAMP



VEHICLE RUNNING WITH CONSTANT SPEED ON A LEVEL ROAD



POWER STATION



6.8 EFFICIENCY

Q.No.14 What is Efficiency? Explain the ideal machine and practical systems.

Ans: Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

Example

Electric motors may be used to pump water, to blow air, to wash clothes, to drill holes, etc. for that they use electric energy. How good a machine is, depends how much output we obtain from it by giving certain input. The ratio of useful output to input energy is very important to judge the working of machine.

Mathematical Form

$$\text{Efficiency} = \frac{\text{Required form of output}}{\text{Total input energy}}$$

Or $$\%\ \text{Efficiency} = \frac{\text{Required form of output}}{\text{Total input energy}} \times 100$$

Ideal Machine

An ideal machine is that which gives an output equal to the total energy used by it. In other words, its efficiency is 100 %. People have tried to design a working system that would be 100 % efficient. But practically such system does not exist.

Practical Systems

Every system meets energy losses due to friction that causes heat, noise etc. these are not the useful forms of energy and go waste. This means we cannot utilize all the energy given to working system. The energy in the required form obtained from working system always less than the energy given to it as input.

6.9 POWER

Q.No.15 What is Power? Write down its unit and define it.

Ans: "Rate of doing work with respect to time is called the power."

Thus $$\text{Power} = \frac{\text{Work}}{\text{time}}$$

If we represent power by 'P', work by 'W' and time by 't', then

$$P = \frac{W}{t}$$

Quantity

Since work is scalar quantity so power is also a scalar quantity.

Unit of power

In System International, the unit of power is watt (W).

Watt

"If a body does a work of one joule in one second then its power will be one watt".

Bigger Units

$1\ KW = 10^3\ W$

$1\ MW = 10^6\ W$

1 horsepower = 746 W

Unit 6: Work and Energy

Multiple Choice Questions

1. **Product of force and distance covered in the direction of force is:**
(a) Acceleration (b) Resistance
(c) Work (d) Specific heat
2. **For work ---------- conditions should be fulfilled:**
(a) 1 (b) 2
(c) 3 (d) 4
3. **Work is -------------- quantity:**
(a) Scalar (b) Vector
(c) Base (d) None of above
4. **Unit of work is:**
(a) N (b) Nm
(c) J (d) Both b & c
5. **Work done will be ----------- if no force act on the body:**
(a) Maximum (b) Minimum
(c) Zero (d) All of above
6. **Work done will be maximum if displacement is ---------- to force:**
(a) Parallel (b) Perpendicular
(c) Tangent (d) Normal
7. **Work done will be zero if displacement is ---------- to force:** **(LHR 2016)**
(a) Parallel (b) Perpendicular
(c) Tangent (d) Normal
8. **Work done will be one --------- if a force of one Newton acts on the body and it covers the distance of 1 meter in the direction of force:**
(a) Watt (b) Joule
(c) Newton (d) Coulomb
9. **One Mega joule is equal to:** **(LHR 2011)**
(a) 10^6 J (b) 10^3 J
(c) 10^9 J (d) 10^2 J
10. **What will be the magnitude of work if a force of 25 N pulls a stone through a distance of 5 m in its direction:**
(a) 25 J (b) 50 J
(c) 75 J (d) 125 J
11. **Which unit is equal to kgm^2s^{-2} in the units given below:**
(a) Joule (b) Newton
(c) Watt (d) Meter
12. **Rate of doing work with respect to time is known as:** **(LHR 2016)**
(a) Energy (b) Power
(c) Momentum (d) None of above
13. **Unit of power is:**
(a) Watt (b) Joule
(c) Newton (d) Coulomb

14. **How much power is used by a 40 kg athlete by climbing 10m high ladder in 10 s:**
(a) 4 W (b) 40 W
(c) 400 W (d) 4000 W

15. **What will be the power of a machine doing 10 J work in 5 seconds?**
(a) 2 W (b) 10 W
(c) 25 W (d) 50 W

16. **Ability of a body to do work is known as: (LHR 2011)**
(a) Force (b) Momentum
(c) Power (d) Energy

17. **There are ---------- basic kinds of energy:**
(a) 1 (b) 2
(c) 3 (d) 4

18. **Energy is --------- quantity:**
(a) Vector (b) Scalar
(c) Base (d) None of above

19. **Unit of Energy in System International is:**
(a) Watt (b) Joule
(c) Newton (d) Coulomb

20. **Energy possessed by a body due to its motion is called ---------- energy:**
(a) Kinetic (b) Potential
(c) Mechanical (d) All of above

21. **A bowler during playing cricket throws a ball of mass 200 g with a velocity of 20 ms^{-1}. Its kinetic energy will be:**
(a) 4 J (b) 40 J
(c) 400 J (d) 4000 J

22. **What will be the kinetic energy of a body if its velocity is doubled? (GRW 2011)**
(a) Doubled (b) Four times
(c) Eight times (d) Half

23. **What will be the kinetic energy of a body if its mass is doubled?**
(a) Doubled (b) Four times
(c) Eight times (d) Half

24. **What will be the kinetic energy of a car of mass 1000 kg moving with a velocity of 20 ms^{-1}?**
(a) 2×10^2 J (b) 2×10^3 J
(c) 2×10^5 J (d) 2×10^7 J

25. **Ability of a body to do work due to its position is called --------- energy: (LHR 2011)**
(a) Kinetic (b) Potential
(c) Mechanical (d) All of above

26. **Ability of a body to do work due to its height from the surface of earth is called _________energy:**
(a) Gravitational Potential (b) Elastic Potential
(c) Chemical Potential (d) Attraction

27. **When a ball is lifted to a height 'h' from the ground, it will posses ------energy:**
(a) Kinetic (b) Gravitational potential
(c) Elastic potential (d) Mechanical

28. **Total energy of the system:**
(a) Increases (b) Decreases
(c) Remains same (d) All of above

29. **For movement of our body ----------- energy is used:**
(a) Heat (b) Electrical

(c) Chemical **(d)** Mechanical

30. **1 hp =**

(a) 726 W **(b)** 736 W

(c) 746 W **(d)** 756 W

31. **For the propagation of signals in our body ---------- energy is used:**

(a) Heat **(b)** Electrical

(c) Chemical **(d)** Mechanical

32. **For maintaining the body temperature ------------ energy is used:**

(a) Heat **(b)** Electrical

(c) Chemical **(d)** Mechanical

33. **Increase in K.E is equal to:**

(a) Increase in P.E **(b)** Decrease in P.E

(c) No effect **(d)** Both a & b

34. **Increase in P.E is equal to:**

(a) Increase in K.E **(b)** Decrease in K.E

(c) No effect **(d)** Both a & b

35. **Decrease in K.E is equal to:**

(a) Increase in P.E **(b)** Decrease in P.E

(c) No effect **(d)** Both a & b

36. **Decrease in P.E is equal to:**

(a) Increase in K.E **(b)** Decrease in K.E

(c) No effect **(d)** Both a & b

37. **A motor lift a weight of 5N up to the height of 2m in 4s. What will be the power of the motor?**

(a) 2.5 W **(b)** 5 W

(c) 20 W **(d)** 10 W

38. **Energy of the water stored in the dam is:** **(GRW 2015)**

(a) Elastic potential energy **(b)** Gravitational potential energy

(c) Kinetic energy **(d)** Mechanical energy

39. **How many types of mechanical energy are?**

(a) 1 **(b)** 2

(c) 3 **(d)** 4

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	c	11	a	21	b	31	b
2	b	12	b	22	b	32	a
3	a	13	a	23	a	33	b
4	d	14	c	24	c	34	b
5	c	15	a	25	b	35	a

6	a	16	d	26	a	36	a
7	b	17	b	27	b	37	a
8	b	18	b	28	c	38	b
9	a	19	b	29	d	39	b
10	d	20	a	30	c		

Unit 6: Work and Energy

Problems

6.1 A man has pulled a cart through 35 m applying a force of 300 N. Find the work done by the man. (GRW 2013)

Given Data

Force applied = F = 300 N
Distance moved by cart = S = 35 m

Required

Work done by the man = W =?

Solution

As we know that

$W = F \times S$

By putting the values, we have

$W = 300 \times 35$
$W = 10500\ J$

Result

Work done by the man = W = 10500 J

6.2 A block weighing 20 N is lifted 6 m vertically upward. Calculate the potential energy stored in it.

Given Data

Weight of the block = W = 20 N
Distance moved vertically upward = h = 6 m

Required

Potential energy of the block = P.E = ?

Solution

As we know that

$W = F \times S$

By putting the values, we have

$W = 20 \times 6$
$W = 120\ J$

Result

Potential energy of the block = P.E = 120 J

6.3 A car weighing 12 kN has speed of 20 ms-1. Find its kinetic energy stored in it. (LHR 2015)

Given Data

Weight of car = w = 12 kN
Speed of car = v = 20 ms-1

Required

Kinetic energy stored in car = K.E = ?

Solution

As we know that

$K.E = \frac{1}{2} mv^2$

By putting the values, we have

$K.E. = \frac{1}{2} \times 1200 \times (20)^2$

$K.E. = \frac{1}{2} \times 1200 \times 400$

$K.E. = 240000\ J$

$K.E. = 240\ kJ$

Result

Kinetic energy stored in car = K.E = 240 kJ

6.4 A 500 g stone is thrown up with a velocity of 15 ms^{-1}. Find its

i) P.E. at its maximum height

ii) K.E. when it hits the ground

Given Data

Mass of the stone = m = 500 g = 0.5 kg

Velocity of the stone = v = 15 ms^{-1}

Required

P.E. at its maximum height = P.E. = ?

K.E. when it hits the ground = K.E. = ?

Solution

As we know that

Potential energy at maximum height = kinetic energy while throwing

Potential energy at maximum height = $\frac{1}{2} mv^2$

By putting the values, we have

Potential energy at maximum height = $\frac{1}{2} \times 0.5 \times (15)^2$

Potential energy at maximum height = $\frac{1}{2} \times 0.5 \times 225$

Potential energy at maximum height = 56.25 J

Also we know that

Kinetic energy while hitting the ground = Potential energy at maximum height

As Potential energy at maximum height = 56.25 J

So Kinetic energy while hitting the ground = 56.25 J

Result

P.E. at its maximum height = P.E. = 56.56 J

K.E. when it hits the ground = K.E. = 56.56 J

6.5 On reaching the top of a slope 6 m high from its bottom, a cyclist has a speed of 1.5 ms^{-1}. Find the kinetic energy and the potential energy of the cyclist. The mass of the cyclist and his bicycle is 40 kg.

Given Data

Speed of the cyclist = v = 1.5 m^{s-1}

Height of slope = h = 6 m

Mass of cyclist and bicycle = m = 40 kg

Required

Kinetic energy of the cyclist = K.E. = ?

Potential energy of the cyclist = P.E = ?

Solution

As we know that

$P.E. = mgh$

By putting the values, we have

$$P.E. = 40 \times 10 \times 6$$

$$P.E. = 2400\ J$$

Also we know that

$$K.E. = \frac{1}{2} mv^2$$

By putting the values, we have

$$K.E. = \frac{1}{2} \times 40 \times (1.5)^2$$

$$K.E = \frac{1}{2} \times 40 \times 2.25$$

$$K.E. = 45\ J$$

Result

Kinetic energy of the cyclist = K.E. = 45 J
Potential energy of the cyclist = P.E = 2400 J

6.6 A motor boat moves at a steady speed of 4 ms^{-1}. Water resistance acting on it is 4000 N. Calculate the power of its engine.

Given Data

Speed of the motor boat = v = 4 ms^{-1}
Water resistance acting on boat = 4000 N

Required

Power of the engine of motor boat = P = ?

Solution

As we know that

$$P = \frac{W}{t}$$

$$= \frac{FS}{t}$$

$$= F\left(\frac{S}{t}\right)$$

$$P = F \times v$$

By putting the values, we have

$$P = 4000 \times 4$$

$$P = 16000\ W$$

$$P = 16\ kW$$

Result

Power of the engine of motor boat = P = 16 kW

6.7 A man pulls a block with a force of 300 N through 50 m in 60 s. Find the power used by him to pull the block. (LHR 2015)

Given Data

Force applied on block = F = 300 N
Distance covered by the block = S = 50 m
Time taken = t = 60 s

Required

Power used to pull the block = P = ?

Solution

As we know that

$$P = \frac{W}{t} = \frac{F \times S}{t}$$

By putting the values, we have

$$P = \frac{3000 \times 50}{60}$$

$$P = \frac{150000}{60}$$

$$P = 250\ W$$

Result

Power used to pull the block = P = 250 W

6.8 A 50 kg man moved 25 steps up in 20 seconds. Find his power, if each step is 16 cm high. (GRW 2014)

Given Data

Mass of man = m = 50 kg
Height of each step = h = 16 cm = 0.16 m
Number of steps = n = 25
Time taken = t = 20 s

Required

Power of the man = P = ?

Solution

Since

$$F = w$$
$$= mg$$
$$= (50)(10)$$
$$= 500\ N$$

Height reached by man = h = 0.16 × 25
= 4 m

As we know that

$$P = \frac{W}{t} = \frac{F \times S}{t}$$

By putting the values, we have

$$P = \frac{500 \times 4}{20}$$

$$P = \frac{2000}{20}$$

$$P = 100\ W$$

Result

Power of the man = P = 100 W

6.9 Calculate the power of a pump which can lift 200 kg of water through a height of 6 m in 10 seconds. (LHR 2013, GRW 2013, 2014)

Given Data

Mass of the water = m = 200 kg
Height attained = h = 6 m
Time taken = t = 10 s

Required

Power of the pump = P = ?

Solutioı

Since

$F = w$

$= mg$

$= 200 \times 10$

$= 2000\ N$

As we know that

$$P = \frac{W}{t} = \frac{F \times S}{t}$$

By putting the values, we have

$$P = \frac{2000 \times 6}{10}$$

$$P = \frac{12000}{10}$$

$P = 1200\ W$

Result

Power of the pump = P = 1200 W

6.10 An electric motor of 1 hp is used to run water pump. The water pump takes 10 minutes to fill an overhead tank. The tank has a capacity of 800 liters and height of 15 m. find the actual work done by the electric motor to fill the tank. Also find the efficiency of the system.

Given Data

Power of the motor = P = 1 hp

Time taken by pump = t = 10 mins = 600 s

Capacity of the tank = v = 800 liters

Height of the tank = h = 15 m

Required

Work done by the motor = W = ?

Efficiency of the system = ?

Solution

As we know that

$$P = \frac{W}{t} \qquad \text{So} \qquad W = P \times t$$

By putting the values, we have

$W = 1\ hp \times 600s$

Or $W = 746\ w \times 600s = 447600\ J$

Now Output = W = mgh

By putting the values, we have

Output = 800 x 10 x 15

Output = 120000 J

We also know that

$$\%\ \text{Efficiency} = \frac{\text{Required form of output}}{\text{Total input energy}} \times 100$$

By putting the values, we have

$$\%\ \text{Efficiency} = \frac{120000\ J}{447600\ J} \times 100$$

% Efficiency = 0.268 x 100

So, % Efficiency = 26.8%

Result

Work done by the motor = W = 447600 J

Efficiency of the system = 26.8%

Unit 7: Properties of Matter

Textbook Exercise Questions

7.1 Encircle the correct answer from the given choices.

i. In which of the following state, molecules do not leave their position: **(LHR 2015, 2016)**

(a) Solid ✓ **(b)** liquid
(c) gas **(d)** plasma

ii. Which of the substances is the lightest one? **(LHR 2016)**

(a) Copper **(b)** mercury
(c) aluminum ✓ **(d)** lead

iii. SI unit of pressure is Pascal, which is equal to?

(a) 10^{-4} Nm^{-2} **(b) 1 Nm^{-2} ✓**
(c) 10^{2} Nm^{-2} **(d)** 10^{3} Nm^{-2}

iv. What should be the approximate length of a glass tube to construct a water barometer?

(a) 0.5 m **(b)** 1 m
(c) 2.5 m **(d) 11 m ✓**

v. According to Archimedes, upthrust is equal to: (LHR 2014, GRW 2015, 2016)

(a) Weight of displace body **(b)** volume of displaced body
(c) mass of displaced liquid **(d) none of these ✓**

vi. The density of a substance can be found with the help of:

(a) Pascal's law **(b)** Hooke's law
(c) Archimedes principle ✓ **(d)** principle of floatation

vii. According to Hooke's law:

(a) Stress x strain = constant **(b) stress/strain = constant ✓**
(c) strain/stress = constant **(d)** stress = strain

7.2 How kinetic molecular model is helpful in differentiating various states of matter?
Ans: See Q. 1 Long Question

7.3 Does there exist a fourth state of matter? What is that?
Ans: Yes, there exists a fourth state of matter called Plasma.
At very high temperature, atoms lose their electrons and become positive ions. This ionic state of matter consisting of ions and electrons is called plasma.

7.4 What is meant by a density? What is its SI unit?
Ans: Density of a substance is defined as its mass per unit volume.
Density = mass of a substance/volume of that substance

Unit

SI unit of density is kilogram per cubic meter ($kg\ m^{-3}$).

7.5 Can we use a hydrometer to measure the density of milk?
Ans: Hydrometer is a device which is used to measure the density of liquids. So it can be used to measure the density of milk.

7.6 Define the term pressure.

Ans: The force acting normally per unit area on the surface of a body is called pressure.

Thus $P = Force/Area$

Or $P = F/A$

Quantity

Pressure is a scalar quantity.

Unit

In SI units, the unit of pressure is $N\ m^{-2}$ also called Pascal (Pa). Thus, $1N\ m^{-2} = 1Pa$.

7.7 It is easy to remove air from a balloon but it is very difficult to remove air from a glass bottle. Why?

Ans: Because the atmospheric pressure acts more easily on balloon as compared to glass bottle, so emptying air is easier from balloon than glass bottle.

7.8 What is barometer?

Ans: The instrument used to measure atmospheric pressure is called barometer. One of the simple barometers is mercury barometer. It consists of a glass tube 1m long closed at one end.

7.9 Why water is not suitable to be used in a barometer?

Ans: Mercury is 13.6 times denser than water. Atmospheric pressure can hold vertical column of water about 13.6 times the height of mercury column at a place. Thus, at sea level, vertical height of water column would be 0.76 m x 13.6 = 10.34 m. Thus, a glass tube more than 10 m long is required to make a water barometer.

7.10 What makes a sucker pressed on a smooth wall sticks to it?

Ans: When a sucker is pressed on a smooth surface, the air pressure below it becomes very small (due to the displaced air) as compared to the air pressure above it. Therefore, it sticks with the smooth surface.

7.11 Why does the atmospheric pressure vary with height?

Ans: As we go high in the atmosphere, the density of the air becomes low. Due to this reason, atmospheric pressure decreases as we go high.

7.12 What does it mean when the atmospheric pressure at place fall suddenly?

Ans: A sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

7.13 What changes are expected in weather if the barometer reading shows a sudden increase?

Ans: A sudden increase in atmospheric pressure means that it will soon followed by a decrease in the atmospheric pressure indicating poor weather ahead.

7.14 State Pascal's law.

Ans: Pressure applied at any point of a liquid enclosed in a container, is transmitted without the loss to all other parts of the liquid.

7.15 Explain the working of hydraulic press.

Ans: See Q.6 Long Question

7.16 What is meant by elasticity?

Ans: The property of matter by virtue of which matter resists any force which tries to change its length, shape or volume is called elasticity.

7.17 State Archimedes principle?

Ans: When object is totally or partially immersed in a liquid, an upthrust act on it equal to the weight of the liquid it displaces.

7.18 What is up thrust? Explain the principle of floatation.

Ans: See Q. 8 & 10 Long Questions

7.19 Explain how a submarine moves up the water surface and down into water.

Ans: See Q. 10 Long Question

7.20 Why does a piece of stone sink in water but a ship with a huge weights floats?

Ans: The upthrust force on stone is much smaller than its weight because weight of the water displaced under stone is very small. While the ships are designed in such a way weight of the water displaced by them is greater than their weight. So upthrust force in case of ships is greater than their weights. So ships float on the surface of water.

7.21 What is Hooke's law? What is meant by elastic limit?

Ans: Hooke's Law

The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body.

Elastic Limit

It is a limit within which a body coves recovers its original length, volume or shape after deforming force is removed is called elastic limit.

When a body crosses this limit, it is permanently deformed and is unable to restore its original state after the stress is removed.

7.22 Take a rubber band. Construct a balance of you own using a rubber band. Check its accuracy by weighing various objects.

Ans: Take a rubber band hang it with a hook. Then pointer is attached at the lower end of it with scale in front of pointer. Different known weights are suspended one by one at the lower end of the rubber band. Mark the pointer positions for each known weight. It is called calibration of scale for weight measurements. This makes a balance for weight measurement.

Unit 7: Properties of Matter

Long Questions

7.1 KINETIC MOLECULAR MODEL OF MATTER

Q.1 Explain different states of matter on the basis of kinetic molecular theory.(LHR 2013)

Ans: Kinetic molecular model is used to explain the three states of matter – solid, liquid, and gas.

(i) Solid

Solids have fixed shapes and volume. Their molecules are held close together. However, they vibrate about their mean positions but do not move from place to place.

Examples are stone, metal spoon, pencil etc.

(ii) Liquids

The distance between the molecules of a liquid is more than in solids. Thus, attractive forces between them are weaker. Like solids, molecules of a liquid also vibrate about their mean position but are not rigidly held with each other. Due to the weaker attractive forces, they can slide over one another. Thus, the liquids can flow. The volume of a certain amount of liquid remains the same but because it can flow hence; it attains the shape of a container to which it is put.

(iii) Gases

Gases such as air have no fixed shape or volume. They can be filled in any container of any shape. Their molecules have random motion and move with very high velocities. In gases, molecules are much farther apart than solids or liquids. Thus, gases are much lighter than solids and liquids. They can be squeezed into smaller volumes.

Pressure of gases

The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container.

(iv) Plasma

The kinetic energy of gas molecules goes on increasing if a gas is heated continuously. This causes the gas molecules move faster and faster. The collisions between atoms and molecules of the gas become so strong that they tear off the atoms. Atoms lose their electrons and become positive ions. This ionic state of matter is called plasma.

Plasma in discharge tubes

Plasma is also formed in gas discharge tubes when electric current passes through these tubes.

Plasma – The Fourth state of Matter

Plasma is also called the fourth state of matter in which gas occurs in its ionic state. Positive ions and electrons get separated in the presence of electric and magnetic field. Plasma also exists in neon and fluorescent tubes when they glow.

Universe formation

Most of the matters that fill the universe are in plasma state. In stars such as our sun, gases exist in their ionic state.

Plasma Good Conductor

Plasma is highly conducting state of mater. It allows electric current to pass through it.

Q.2 What is atmospheric pressure? And explain atmospheric pressure with the help of an experiment.

Ans: The earth is surrounded by a cover of air is called atmosphere. It extends to a few hundred kilometers above sea level. Just as certain sea creatures live at the bottom of ocean, we live at the bottom of a huge ocean of air. Air is the mixture of gases. The density of air in the atmosphere is not uniform. It decreases continuously as we go up.

Atmospheric pressure acts in all directions.

Examples

Soap bubbles expand till the pressure of air in them is equal to the atmospheric pressure. Soap bubbles so formed have spherical shapes because the atmospheric pressure acts on a bubble equally in all directions.

A balloon expands as we fill air into it. The balloon will expand in all directions.

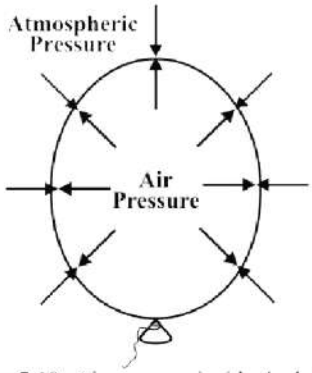


Figure 7.10: Air pressure inside the balloon is equal to the atmospheric pressure.

Experiment

The fact that atmosphere exerts pressure can be explained by simple experiment. Take an empty tin can with a lid.

Open its cap and put some water in it. Place it over flame. Wait till water begins to boil and the steam expels the air out of the can. Remove it from the flame. Close the can firmly by its cap. Now place the can under tape water. The can will squeeze due to atmospheric pressure.

When the can is cooled by tap water, the steam in it condenses. As the steam changes into water, it leaves an empty space behind it. This lowers the pressure inside the can as compared to the atmospheric pressure outside the can. This will cause that can to collapse from all directions. This experiment shows that atmosphere exerts pressure in all directions.

Measuring Atmospheric Pressure **(LHR 2014)**

Q.3 Which device is used to measure the atmospheric pressure? Explain the measurement of atmospheric pressure by using barometer.

A simple device used to measure the atmospheric pressure is barometer.

Barometer

The instruments that measure atmospheric pressure are called barometers. One of the simple barometers is a mercury barometer. It consists of a glass tube 1 m long closed at one end.

Measurement

After filling it with mercury, it is inverted in a mercury trough. Mercury in the tube descends and stops at a certain height. The column of mercury held in the tube exerts pressure at its base. At the sea level the height of mercury column above the mercury in the trough is found to be about 76 cm. pressure exerted by 76 cm of air column is nearly 101,300 Nm^{-2} equal to atmospheric pressure.

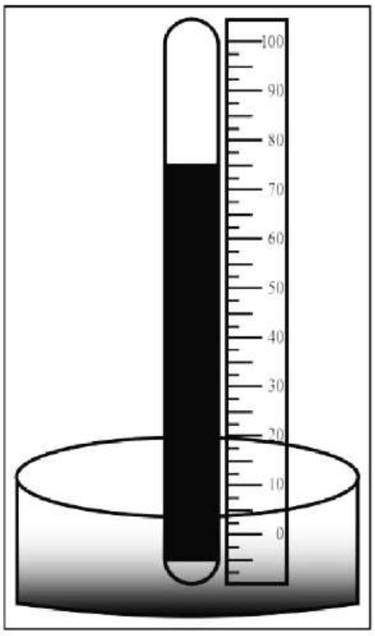


Figure 7.12: A mercury barometer

It is common to express atmospheric pressure in terms of the height of mercury column. As the atmospheric pressure at a place does not remains constant, hence, the height of mercury column also varies with atmospheric pressure.

Atmospheric pressure at sea level

At sea level, the atmospheric pressure is about 101,300 Pa or 101,300 Nm^{-2}.

Mercury in barometer instead of water

Mercury is 13.6 times denser than water. Atmospheric pressure can hold vertical column of water is about 13.6 times the height of mercury column at a place. Thus, at sea level, vertical height of water column would be 0.76 m x 13.6 = 10.34 m. Thus, a glass tube more than 10 m long is required to make a water barometer.

Variation in Atmospheric Pressure

Q.4 Write a note on variation in atmospheric pressure.

Ans: The atmospheric pressure decreases as we go up. The atmospheric pressure on mountains is lower than at sea level. At a height of about 30 km, the atmospheric pressure becomes only 7 mm of mercury which is approximately 1000 Pa. it would become zero at an altitude where is no air. Thus we can determine the altitude of a place by knowing the atmospheric pressure at that place.

Effect of weather on atmospheric pressure

- On a hot day, air above the Earth becomes hot and expands. This causes a fall of atmospheric pressure in that region.
- During cold chilly nights, air above the Earth cools down. This causes an increase in atmospheric pressure.

Expected weather changes due to variation of atmospheric pressure

The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions at that place.

Decrease in atmospheric pressure

- A gradual and average drop in atmospheric pressure means a low pressure in a neighboring locality.
- Minor but rapid fall in atmosphere indicates a windy and showery condition in the nearby region.
- A decrease in atmospheric pressure accompanied by breeze and rain.
- A sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

Increase in atmospheric pressure

- An increasing atmospheric pressure with a decline later on predicts an intense weather conditions.
- A gradual large increase in the atmospheric pressure indicates a long spell of pleasant weather.
- A rapid increase in atmospheric pressure means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

7.5 PRESSURE IN LIQUIDS

Q.5 Define pressure in liquids. Derive its mathematical formula.

Ans: Liquids exert pressure. The pressure of a liquid acts in all directions. If we take pressure sensor (a device that measures pressure) inside a liquid, then the pressure of the liquid varies with the depth of sensor.

Mathematical Derivation

Consider a surface area A in a liquid at a depth h as shown in figure. The length of the cylinder of liquid over this surface will be h. The force acting on this surface will be the weight w of the liquid above this surface. If ρ is the density of the liquid and m is mass of the liquid above the surface, then

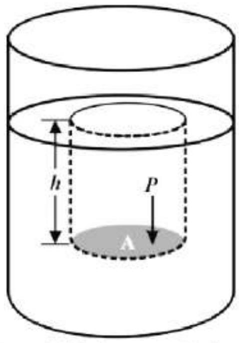


Figure 7.13: Pressure of a liquid at a depth *h*.

Mass of the liquid $= m =$ volume x density

$= m = (A \times h) \times \rho$

Force acting on area A $= F = w = mg$

$= A\,h\,\rho\,g$

As pressure $= P = F/A$

So $= \dfrac{Ah\rho g}{A}$

Therefore, $P = \rho\,g\,h$

The above equation gives the pressure at a depth h in a liquid of density ρ. It show that its pressure in a liquid increases with depth.

Pascal's Law (GRW 2014)

Q.6 State Pascal's Law. Write down the application of Pascal's law.

Ans: Pressure applied at any point of a liquid enclosed in a container, is transmitted without the loss to all other parts of the liquid.

An external force applied on the surface of a liquid increases the liquid pressure at the surface of the liquid. This increase in liquid pressure is transmitted equally in all direction and to the walls of the container in which it is filled.

Applications of Pascal's Law (Hydraulic Press) **(LHR 2014)**

Hydraulic press is a machine which works on the principle of Pascal's law. It consists of two cylinders which are fitted with pistons of cross – sectional area a and A. The object is to be compressed is placed over the piston of large cross – sectional area A. the Force is applied on the piston of cross – sectional area a.

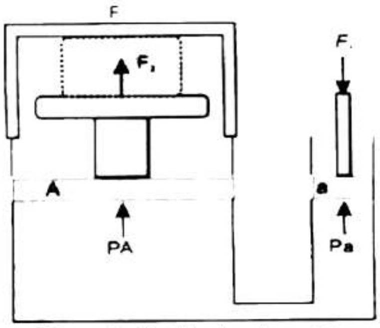


Figure 7.16: A hydraulic press

The pressure P produced by small piston is transmitted through the liquid and acts on the on the large piston and a force F_2 acts on A which is much larger than F_1.

Mathematical form

Pressure on piston of small area a is given by,

$$P = \frac{F_1}{a}$$

By applying Pascal's law, the pressure on the larger piston of area A will be same as on the small piston.

$$P = \frac{F_2}{A}$$

By comparing the above equations, we have

$$\frac{F_1}{a} = \frac{F_2}{A}$$

So, $$F_2 = F_1 \times \frac{A}{a}$$

Since the ratio A/a is greater than 1, hence the force F_2 acts on the larger piston is greater than the force F_1 on the smaller piston. Hydraulic systems working in this way are known as force multipliers.

Braking System in Vehicles

Q.7 Explain the braking system of the vehicles.

Ans: The brakes of cars, buses etc. work on the principle of Pascal's law. In such a type of brakes, when brake pedal is pushed, it exerts pressure on the master cylinder, which increases the liquid pressure in the cylinder. The liquid pressure is transmitted equally through the liquid in the metal pipes. Due to the increase pressure of the liquid pressure, the pistons in the cylinder mover outwards pressing the brakes pad with brake drums. The force of friction between friction the brake pads and the brake drum stops the wheels.

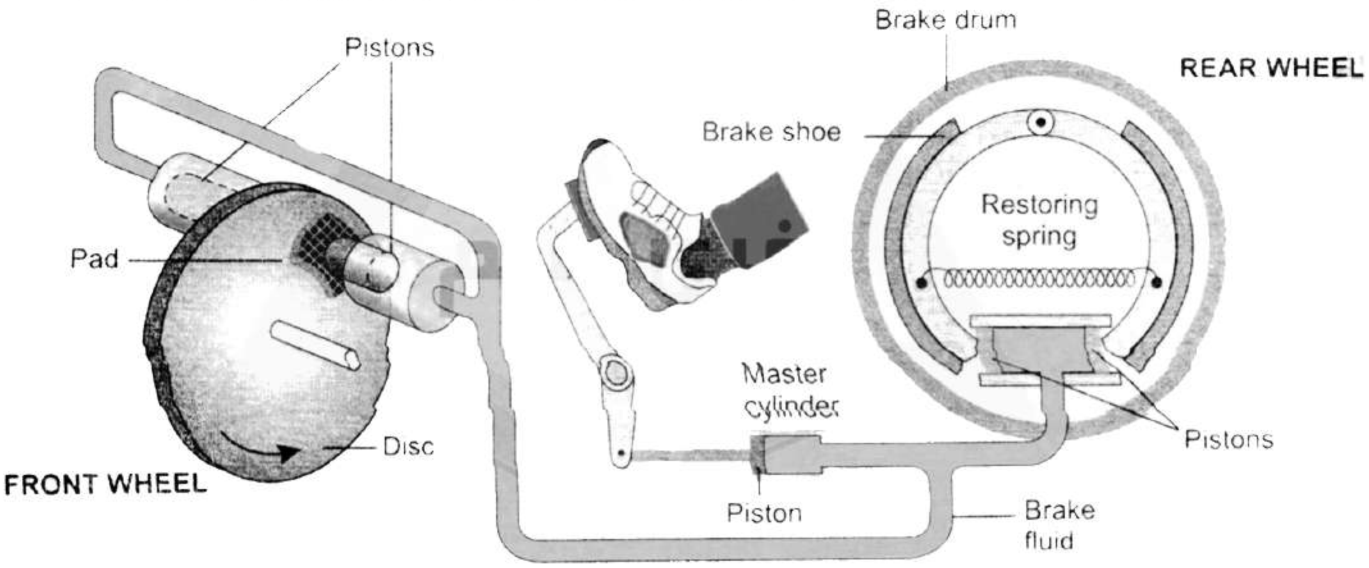


Figure 7.17: A hydraulic brake of a car

7.6 ARCHIMEDES PRINCIPLE

Q.8 State and explain Archimedes Principle. **(GRW 2015)**

Ans: Introduction

More than two thousands years ago, the Greek scientist, Archimedes noticed the upthrust force of the liquid.

Up thrust force

There is an upward force which acts on an object kept inside a liquid. As a result an apparent loss of weight is observed in the object. This upward force acting on the object is called the upthrust of the liquid.

Statement

When object is totally or partially immersed in a liquid, an upthrust act on it equal to the weight of the liquid it displaces.

Explanation

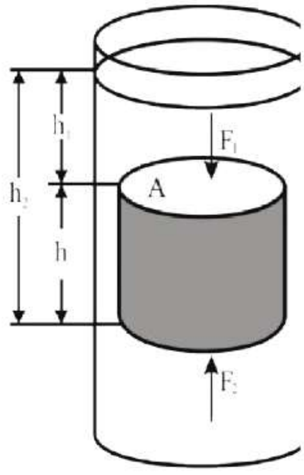


Figure 7.18: Upthrust on a l immersed in a liquid is equa weight of the liquid displace

Consider a solid cylinder of cross – sectional area A and height h immersed in a liquid as shown in figure. Let h_1 and h_2 be the depth of the top and bottom surfaces of the cylinder respectively from the surface of the liquid.

Then $$h_2 - h_1 = h$$

If P_1 and P_2 are the liquid pressures at the depth h_1 and h_2 respectively and ρ is its density, then

$$P_1 = \rho g h_1$$
$$P_2 = \rho g h_2$$

Let the force F_1 is exerted at the cylinder top by the liquid due to pressure P_1 and the force F_2 is exerted at the bottom of the cylinder due to P_2.

So $$F_1 = \rho g h_1 A$$
$$F_2 = \rho g h_2 A$$

F_1 and F_2 are acting on the opposite faces of the cylinder. Therefore, the net force F will be $F_2 - F_1$ in the direction of F_2. The net force F on the cylinder is called the upthrust of the liquid.

Therefore, $F_2 - F_1 = \rho g h_2 A - \rho g h_1 A$

$= \rho g A (h_2 - h_1)$

OR upthrust of liquid $= \rho g h A$

OR $= \rho g V$

Here Ah is the volume V of the cylinder and equal to the volume of the liquid displaced by the cylinder. Therefore, $\rho g V$ is the weight of the liquid displaced. The above equation shows that an upthrust acts on the body immersed in a liquid and is equal to the weight of liquid displaced, which is Archimedes principle.

Density of an Object

Q.9 How density of an object can be found by Archimedes principle?

Ans: Archimedes principle is also helpful to determine the density of an object. The ratio in the weights of a body with an equal volume of the liquid is the same as in their densities.

Let Density of the object $= D$

Density of the liquid $= \rho$

Weight of the object $= w_1$

Weight of equal volume of liquid $= w = w_1 - w_2$

Here w_2 is the weight of solid in liquid. According to Archimedes principle, w_2 is less than its actual weight w_1 by an amount w.

7.7 PRINCIPLE OF FLOATATION (GRW 2015)

Q.10 Explain the Principle of Floatation.

Ans: An object sinks if its weight is greater than the up thrust force acting on it. An object floats if its weight is equal or less than the up thrust. When an object floats in a fluid, the up thrust acting on it is equal to the weight of the object. In case of floating object, the object may be partially immersed. The up thrust is always equal to the fluid displaced by the object. This is principle of floatation. This states that:

"A floating object displaces a fluid having weight equal to weight of the object."
Archimedes principle is applicable on liquids as well as gases. We find numerous applications of this principle in daily life.

Ships and Submarines

A wooden block floats on water. It is because the weight of an equal volume of water is greater than the weight of the block. According to the principle of floatation, a body floats if it displaces water equal to the weight of the body when it is partially or completely immersed in water.

Ships

Ships and boats are designed on the same principle of floatation. They carry passengers and goods over water. It would sink in water if its weight including the weight of its passengers and goods becomes greater than the upthrust of water.

Submarines

A submarine can travel over as well as under water. It also works on the principle of floatation. It floats over water when the weight of the water equal to its volume is greater than its weight. Under this condition, it is similar to a ship and remains partially above water level. It has a system of tanks which can be filled with and emptied from sea water. When these tanks are filled with sea water, the weight of the submarine increases. As soon as its weight becomes greater than the upthrust, it dives into water and remains under water. To come up on the surface, the tanks are emptied from sea water.

7.9 HOOKE'S LAW

Q.11 State and explain the Hooke's Law.

Ans: The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body.

Mathematical Formula

Stress α strain

Stress = constant x strain

Or $\dfrac{\text{Stress}}{\text{Strain}} = \text{constant}$

Hooke's law is applicable to all kinds of deformation and all types of matter i.e. solids, liquids or gases within certain limit.

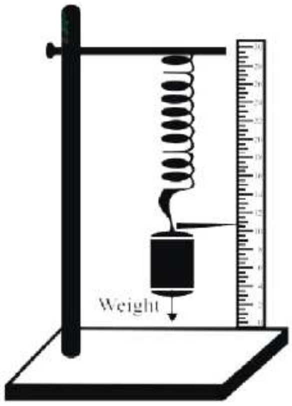


Figure7.23: Extension in the spring depends upon the load

Elastic Limit

It is a limit with which a body recovers to original length, volume or shape after deforming force is removed. This limit is called the elastic limit.

When a stress crosses this limit, called the elastic limit, a body is permanently deformed and is unable to restore its original state after the stress is removed.

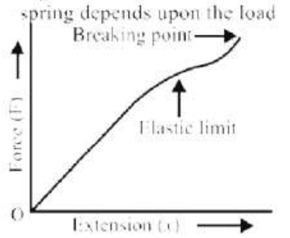


Figure 7.24: Graph between force and extension

Young's Modulus (LHR 2015)

Q.12 Define Young's Modulus and derive its mathematical formula.

Ans: The ration of stress and strain is a constant within the elastic limit, this constant is called the Young's Modulus.

Mathematical Form

Consider a long bar of length Lo and cross – sectional area A. Let an external force F equal to weight stretches it such that the stretched length becomes L.

Mathematically,

Young's modulus = Y = Stress/Tensile strain

Let ΔL be the change in length of the rod, then

$$\Delta L = L - L_o$$

Since $$\text{Stress} = \frac{\text{Force}}{\text{Area}} = F/A$$

And $$\text{Tensile Strain} = \frac{L - L_o}{L_o} = \Delta L/L_o$$

As Young's modulus = Y = Stress/Tensile strain

So $$= \frac{F}{A} \text{ x } \frac{L_o}{L}$$

Therefore, $$= \frac{F \times L_o}{A \times L}$$

Unit

SI unit of Young's Modulus is Newton per square meter ($N\ m^{-2}$)

Unit 7: Properties of Matter

Multiple Choice Questions

1. **The property of the matter due to which it restores its size and shape when force ceases to act on it:**
   (a) Inertia **(b)** Elasticity
   (c) Permittivity **(d)** Rigidity
2. **The force that acts on unit area of an object and thus changes its shape or size:**
   (a) Stress **(b)** Strain
   (c) Yong's Modulus **(d)** Elastic limit
3. **In system international, the unit of stress is:**
   (a) Nm^{-2} **(b)** Nm^{-1}
   (c) Nm **(d)** None of above
4. **The ratio of change in length to the original length is:**
   (a) Stress **(b)** Tensile strain
   (c) Young's Modulus **(d)** Elastic limit
5. **When stress is increased, the strain also goes on:** **(LHR 2016)**
   (a) Decreasing **(b)** Increasing
   (c) Constant **(d)** All of above
6. **The law about stress and strain is presented by:**
   (a) Hook **(b)** Newton
   (c) Joule **(d)** Archimedes
7. **According to Hooke's law, within the elastic limit stress and strain has ------------- proportion:**
   (a) Inverse **(b)** Direct
   (c) Same **(d)** None of above
8. **The ratio of tensile stress and tensile strain is:**
   (a) Variable **(b)** Pascal's Law
   (c) non-uniform **(d)** None of above
9. **The unit of Young's modulus is:**
   (a) Nm^{-2} **(b)** Nm^{-1}
   (c) Nm **(d)** None of above
10. **The force exerted perpendicularly on unit area of an object is called:**
    (a) Strain **(b)** Constant
    (c) Pressure **(d)** Work
11. **The unit of pressure is:**
    (a) Nm^{-2} **(b)** Nm^{-1}
    (c) Pa **(d)** Both a & c
12. **Pressure depends upon:**
    (a) Density **(b)** Depth
    (c) Temperature **(d)** Both a & b
13. **If a body is at a depth of 'h' from the liquid surface of density 'ρ', then the pressure 'P' on that body is:**
    (a) $P = w/t$ **(b)** $P = \rho gV$
    (c) $P = \rho gh$ **(d)** $P = F/a$
14. **The law about pressure on the object is presented by:**
    (a) Joule **(b)** Pascal
    (c) Newton **(d)** Galileo

15. **Hydraulic press is based on:** **(GRW 2014)**
(a) Joule's law **(b)** Pascal law
(c) Newton's law **(d)** Young's Modulus

16. **If pressure is exerted on a liquid, liquid transmits it:**
(a) Variably **(b)** Equally
(c) In all directions **(d)** both b & c

17. **Hydraulic brake works on the principle of:** **(GRW 2014)**
(a) Hydraulic press **(b)** Pascal law
(c) Joule's law **(d)** Both a & b

18. **---------------- tells about the floating and sinking of objects:**
(a) Pascal's law **(b)** Newton's law
(c) Archimedes principle **(d)** None of them

19. **Due to pressure difference on an object, an upward force acts on the object known as:**
(a) Weight **(b)** Buoyant force
(c) Stress **(d)** All of above

20. **Buoyant force is equal to the --------- of the liquid displaced by the object:**
(a) Volume **(b)** Density
(c) Weight **(d)** All of above

21. **The object will float on the liquid surface when:**
(a) $W > F$ **(b)** $W < F$
(c) $W = F$ **(d)** None of above

22. **The object will sink in the liquid surface when:**
(a) $W > F$ **(b)** $W < F$
(c) $W = F$ **(d)** None of above

23. **Submarine works on the principle of:**
(a) Pascal's law **(b)** Newton's law
(c) Archimedes principle **(d)** None of them

24. **When temperature of the gas increases, gas pressure -------------:**
(a) Increases **(b)** Decreases
(c) Remains same **(d)** None of above

25. **If quantity of the gas is increased in the container then gas pressure -------:**
(a) Increases **(b)** Decreases
(c) Remains same **(d)** None of above

26. **According to Kinetic Molecular theory, gases exert pressure on the walls of the container due to their:**
(a) Weight **(b)** Mass
(c) Collisions **(d)** All of above

27. **The molecules of the matter are always remain in the state of:**
(a) Rest **(b)** Plasma
(c) Motion **(d)** Tension

28. **The energy possessed by the molecules of the matter is due to its motion:**
(a) P.E. **(b)** K.E.
(c) Sound **(d)** None of above

29. **When temperature of the matter increases, intermolecular forces ------:**
(a) Increases **(b)** Decreases
(c) Remains same **(d)** None of above

30. **Molecules of which state of matter have strongest attractive for**
(a) Solid **(b)** Liquid
(c) Gasses **(d)** Plasma

31. **How many states of mother are?**
(a) 2 **(b)** 3
(c) 4 **(d)** many

32. **Weakest attractive forces are in**
(a) solid **(b)** liquid

15. **Hydraulic press is based on:** **(GRW 2014)**
(a) Joule's law **(b)** Pascal law
(c) Newton's law **(d)** Young's Modulus

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31. **How many states of mother are?**
(a) 2 **(b)** 3
(c) 4 **(d)** many

32. **Weakest attractive forces are in**
(a) solid **(b)** liquid

(c) gases (d) Plasma

33. **Weakest attractive forces are in**
(a) solid (b) liquid
(c) gases (d) plasma

34. **Ionic state of matter is called** **(GRW 2013)**
(a) gas (b) plasma
(c) liquid (d) none of these

35. **Plasma is**
(a) Good conductor (b) Bad conductor
(c) Semi conductor (d) non conductor

36. **Unit of density** **(LHR 2013)**
(a) kg m^3 (b) kg m^{-2}
(c) kg m^{-3} (d) kg m^2

37. **Unit of pressure is** **(LHR 2013)**
(a) Nm^{-2} (b) Pa
(c) Nm (d) Both a & b

38. **The instrument used to measure atmospheric pressure**
(a) Colorimeter (b) Hypsometer
(c) Barometer (d) None of these

39. **A solid object is:**
(a) Not elastic below the elastic limit (b) Elastic above the elastic limit
(c) Elastic below the elastic limit (d) None of above

ANSWER KEY

Q.	Ans	Q.	Ans	Q.	Ans	Q.	Ans
1	b	11	d	21	b	31	c
2	a	12	d	22	a	32	c
3	a	13	c	23	c	33	c
4	b	14	b	24	a	34	b
5	b	15	b	25	a	35	c
6	a	16	d	26	d	36	c
7	b	17	b	27	c	37	d
8	d	18	c	28	b	38	c
9	a	19	b	29	b	39	c
10	c	20	c	30	a		

Unit 7: Properties of Matter

Problems

7.1 A wooden block measuring 40 cm x 10cm x 5 cm has a mass of 850 g. find the density of the wood.

Given Data

Volume of wooden block = v = 40 cm x 10 cm x 5 cm = 2000 cm^3 = 2 x 10^{-3} m^3

Mass of wooden block = m = 850 g = 0.85 kg

Required

Density of wooden block = d = ?

Solution

As we know that

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

By putting the values, we have

$$\text{Density} = \frac{0.85}{2\times10^{-3}}$$

$$\text{Density} = 0.425 \times 10^{3}\ \text{kg m}^{-3}$$

OR $\text{Density} = 425\ \text{kg m}^{-3}$

Result

Density of wooden block = d = 425 kgm^{-3}

7.2 How much would be the volume of the ice formed by freezing 1 liter of water? (LHR 2014)

Given Data

Volume of water = V_1 = 1 litre

Required

Volume of ice on freezing = V_2 = ?

Solution

As we know that

$$\frac{\text{Volume of ice}}{\text{volume of water}} = \frac{\text{density of water}}{\text{density of ice}}$$

So $$\text{volume of ice} = \left(\frac{\text{density of water}}{\text{density of ice}}\right) \times \text{volume of water}$$

Putting values, we have

Volume of ice = (1000/920) x 1

Volume of ice = 1.09 litres

Result

Volume of ice on freezing = V_2 = 1.09 litres

7.3 (i) **Calculate the volume of the following objects.**

(i) An iron sphere of mass 5 kg, the density of iron is 8200 kgm^{-3}.
(ii) 200 g of lead shot having density 11300 kgm^{-3}.
(iii)A gold bar of mass 0.2 kg. the density of gold is 19300 kgm^{-3}.

(i) An iron sphere of mass 5 kg, the density of iron is 8200 kgm^{-3}.

Given Data

Mass of iron sphere = m = 5 kg
Density of iron = d = 8200 kgm^{-3}

Required

Volume of iron sphere = V = ?

Solution

As we know that

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

By putting the values, we have

$$\text{Volume} = \frac{5}{8200}$$

$$\text{Volume} = 0.00069\ m^3$$

OR $\text{Volume} = 6.9 \times 10^{-4}\ m^3$

Result

Volume of iron sphere = V = $6.9 \times 10^{-4}\ m^3$

7.3 (ii) 200 g of lead shot having density 11300 kgm^{-3}. **(LHR 2013)**

Given Data

Mass of lead shot = m = 200 g = 0.2 kg
Density of lead = d = 11300 kgm^{-3}

Required

Volume of lead shot = v = ?

Solution

As we know that

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

By putting the values, we have

$$\text{Volume} = \frac{0.2}{11300}$$

$$\text{Volume} = 0.000017699\ m^3$$

OR $\text{Volume} = 1.77 \times 10^{-5}\ m^3$

Result

Volume of lead shot = v = $1.77 \times 10^{-5}\ m^3$

7.3 (iii) A gold bar of mass 0.2 kg. the density of gold is 19300 kgm^{-3}. **(LHR 2016)**

Given Data

Mass of gold bar = m = 0.2 kg
Density of gold = d = 19300 kgm^{-3}

Required

Volume of gold bar = v = ?

Solution

As we know that

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

By putting the values, we have

$$\text{Volume} = \frac{0.2}{19300}$$

$$\text{Volume} = 0.00001036\ m^3$$

OR $\quad \text{Volume} = 1.04 \times 10^{-5}\ m^3$

Result

Volume of gold bar = v = $1.04 \times 10^{-5}\ m^3$

7.4 The density of air is $1.3\ kgm^{-3}$. Find the mass of air in room measuring 8 m x 5 m x 4 m. (GRW 2016)

Given Data

Density of air = d = $1.3\ kgm^{-3}$

Volume of air = v = 8 m x 5 m x 4 m = $160\ m^3$

Required

Mass of air = m = ?

Solution

As we know that

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

So $\quad$ Mass = density x volume

By putting the values, we have

$$\text{Mass} = 1.3 \times 160$$

$$\text{Mass} = 208\ kg$$

Result

Mass of air = m = 208 kg

7.5 A student passes her palm by her thumb with a force of 75 N. how much would be the pressure under her thumb having contact area $1.5\ cm^2$?

Given Data

Force exerted by student = F = 75 N

Contact area = A = $1.5\ cm^2 = 1.5 \times 10^{-4}\ m^2$

Required

Pressure under the thumb = P = ?

Solution

As we know that

$$P = \frac{F}{A}$$

By putting the values, we have

$$P = \frac{75}{1.5 \times 10^{-4}}$$

$$P = 50 \times 10^{4}\ Nm^{-2}$$

$P = 5 \times 10^5\ Nm^{-2}$

Result

Pressure under the thumb = $P = 5 \times 10^5\ Nm^{-2}$

7.6 The head of the pin is a square of side 10 mm. find the pressure on it due to a force of 20 N. (GRW 2014)

Given Data

Force applied = F = 20 N

Side of head of pin = $L = 10\ mm = 10 \times 10^{-3}\ m$

Area of head of pin = $A = L \times L = 10 \times 10^{-3}\ m \times 10 \times 10^{-3}\ m$

$= 100 \times 10^{-6}\ m^2 = 1 \times 10^{-4}\ m^2$

Required

Pressure exerted by head of pin = P = ?

Solution

As we know that

$$P = \frac{F}{A}$$

By putting the values, we have

$$P = \frac{20}{1 \times 10^{-4}}$$

$P = 20 \times 10^4\ Nm^{-2}$

$P = 2 \times 10^5\ Nm^{-2}$

Result

Pressure exerted by head of pin = $P = 2 \times 10^5\ Nm^{-2}$

7.7 A uniform rectangular block of wood 20 cm x 7.5 cm x 7.5 cm and of mass 1000 g stands on a horizontal surface with its longest edge vertical. Find

(i) The pressure exerted by the block on the surface

(ii) Density of the wood

Given Data

Mass of wooden block = m = 1000 g = 1 kg

Volume of wooden block = V = 20 cm x 7.5 cm x 7.5 cm

$= 0.001125\ m^3$ or 1.125×10^{-3}

Area of wooden block = A = 7.5 cm x 7.5 cm

$= 0.005625\ m^2$ or $5.625 \times 10^{-3}\ m^2$

Required

(i) The pressure exerted by the block on the surface = P = ?

(ii) Density of wood = d =?

Solution

As we know that

$V = L \times W \times H$

By putting the values, we have

$V = 20\ cm \times 7.5\ cm \times 7.5\ cm = 1125\ cm^3 = 0.001125\ m^3$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

By putting the values, we have

$$\text{Density} = \frac{1}{0.001125}$$

$\text{Density} = 888.89\ kgm^{-3} = 889\ kgm^{-3}$

As we know that

$$P = \frac{F}{A}$$

By putting the values, we have

$$P = \frac{10}{0.005625}$$

$P = 1778\ Nm^{-2}$

Result

(i) The pressure exerted by the block on the surface = P = 1778 Nm^{-2}
(ii) Density of wood = d = 889 kgm^{-3}

7.8 A cube of glass of 5 cm side and mass 306 g, has a cavity inside it. If the density of the glass is 2.55 gcm^{-3}. Find the volume of the cavity.

Given Data

Length of side of glass cube = L = 5 cm
Volume of glass cube = v = $L^3 = (5\ cm)^3 = 125\ cm^3$
$= 125 \times 10^{-6}\ m^3 = 1.25 \times 10^{-4}\ m^3$
Mass of cube = m = 306 g = 0.306 kg = 3.06×10^{-1} kg
Density of glass = d = 2.25 gcm^{-3} = $2.55 \times 10^3 kg\ m^{-3}$

Required

Volume of cavity inside the glass cube = V = ?

Solution

Volume without cavity $= 1.25 \times 10^{-4}\ m^3$
Volume with cavity = mass/density
$= (3.06 \times 10^{-1})/(2.55 \times 10^3)$
$= 1.20 \times 10^{-4}\ m^3$
Volume of cavity = volume without cavity – volume with cavity
$= 1.25 \times 10^{-4}\ m^3 - 1.20 \times 10^{-4}\ m^3$
$= 0.05 \times 10^{-4}\ m^3$
$= 5 \times 10^{-6}\ m^3$ or $5\ cm^3$

Result

Volume of cavity inside the glass cube = v = 5 cm^3

7.9 An object has weight 18 N in air. Its weight is found to be 11.4 N when immersed in water. Calculate its density. Can you guess the material of the object? (GRW 2014)

Given Data

Weight of object in air = w_1 = 18 N
Weight of object in water = w_2 = 11.4 N
Density of water = ρ_w = 1000 kgm^{-3}
Gravitational acceleration = g = 10 ms^{-2}
Weight of equal volume of water = w = $w_1 - w_2$ = 18 N – 11.4 N = 6.6 N

Required

Density of material = D_m = ?
Name of material = ?

Solution

As we know that

$$\frac{D}{\rho} = \frac{w_1}{w}$$

By putting the value, we have

$$\frac{D}{1000} = \frac{18}{6.6}$$

$$D = \frac{18000}{6.6}$$

$$D = 2727\,\text{Kgm}^{-3}$$

Result

Density of material = D_m = 2727 Kgm^{-3}

As we know that density of aluminum is approximately equal to the density found in the numerical. So, the material is aluminum.

7.10 A solid block of wood of density 0.6 gcm^{-3} weighs 3.06 N in air. Determine,

(i) Volume of the block

(ii) The volume of block immersed when placed freely in liquid of density 0.9 gcm-3.

Given Data

Density of wooden block = d = 0.6 gcm^{-3}

Weight of the wooden block = w = 3.06 N

Density of liquid = d_l = 0.9 gcm^{-3}

Required

Volume of the wooden block = V_1 = ?

Volume of block when immersed in liquid = V_2 = ?

Solution

As we know that

$$\text{Volume} = \text{mass/ density}$$

$$V_1 = 0.306/(0.6 \times 10^3) \quad = 0.51 \times 10^{-3}\ \text{m}^3 \text{ or } 510\text{cm}^3$$

As we also know that

$$\text{Upward thrust} = \text{weight of the liquid displaced}$$

$$\text{Weight} = 10 \times \text{volume} \times \text{density}$$

$$3.06 = 10 \times \text{volume} \times 0.9 \times 10^3$$

$$\text{Volume} = 3.06/(9 \times 10^3)$$

$$V_2 = 0.00034\ \text{m}^3 \text{ or } 34\ \text{cm}^3$$

Result

Volume of the wooden block = V_1 = 510 cm^3

Volume of block when immersed in liquid = V_2 = 34 cm^3

7.11 The diameter of the piston of hydraulic press is 30 cm. How much force is required a car weighing 20000 N on its piston, if the diameter of the piston of the pump is 3 cm.

(GRW 2016)

Given Data

Diameter of the piston of hydraulic press = D = 30 cm = 0.3 m

Diameter of the piston of pump = d = 3 cm = 0.03 m

Weight of the car lifted by hydraulic press = w = F_2 = 20000 N

Required

Force applied on piston of pump = F_1 = ?

Solution

As we know that

$$A = \frac{\pi D^2}{4}$$

(i) Larger piston

By putting the values, we have

$$A = \frac{3.14 \times (3 \times 10^{-1})^2}{4}$$

$$A = \frac{3.14 \times 9 \times 10^{-2}}{4}$$

$$A = \frac{28.26 \times 10^{-2}}{4}$$

$$A = 7.065 \text{ x } 10^{-2} \text{ m}^2$$

(ii) Smaller piston

By putting the value, we have

$$a = \frac{3.14 \times (3 \times 10^{-2})^2}{4}$$

$$a = \frac{3.14 \times 9 \times 10^{-4}}{4}$$

$$a = \frac{28.26 \times 10^{-4}}{4}$$

$$a = 7.065 \text{ x } 10^{-4} \text{ m}^2$$

From Pascal's law, we have

$$\frac{F_1}{a} = \frac{F_2}{A}$$

By putting the values, we have

$$\frac{F_1}{7.065 \times 10^{-4}} = \frac{20000}{7.065 \times 10^{-2}}$$

$$F_1 = \frac{20000 \times 7.065 \times 10^{-4}}{7.065 \times 10^{-2}}$$

$$F_1 = \frac{20000}{100}$$

$$F_1 = 200 \text{ N}$$

Result

Force applied on piston of pump = F_1 = 200 N

7.12 A steel wire of cross-sectional area 2 x 10^{-5} m^2 is stretched through 2 mm by a force of 4000 N. Find the young's modulus of the wire. The length of the wire is 2m.

Given Data

Length of the wire = L_o = 2 m
Area of steel wire = A = 2 x 10^{-5} m^2
Increase in length of wire = ΔL = 2 mm = 2 x 10^{-3} m
Force applied = F = 4000 N

Required

Young's modulus of wire = Y = ?

Solution

As we know that

$$Y = \frac{F \times L}{A \times \Delta L}$$

By putting the values, we have

$$Y = \frac{4000 \times 2}{2 \times 10^{-5} \times 2 \times 10^{-3}}$$

$$Y = \frac{2000}{10^{-5} \times 10^{-3}}$$

$$Y = 2000 \text{ x } 10^{8} \text{ Nm}^{-2} = 2 \text{ x } 10^{3} \text{ x } 10^{8} \text{ Nm}^{-2}$$

$$Y = 2 \text{ x } 10^{11} \text{ Nm}^{-2}$$

Result

Young's modulus of wire = Y = 2 x 10^{11} Nm^{-2}

Unit 8: Thermal Properties of Matter

Textbook Exercise Questions

8.1 Encircle the correct answer from the given choices.

i. Water freezes at: **(LHR 2013, 2016)**

(a) 0 ºF **(b) 32 ºF ✓**
(c) -273 K **(d)** 0 K

ii. Normal human body temperature is: **(LHR 2016)**

(a) 15 ºC **(b) 37 ºC ✓**
(c) 37 ºF **(d)** 98.6 ºF

iii. Mercury is used as thermometric material because it has:

(a) Uniform thermal expansion **(b)** low freezing point
(c) small heat capacity **(d) all of the above properties ✓**

iv. Which of the following material has large specific heat? **(GRW 2013)**

(a) Copper **(b)** ice
(c) water ✓ **(d)** mercury

v. Which of the following material has large value of temperature coefficient of linear expansion?

(a) Aluminum ✓ **(b)** gold
(c) brass **(d)** steel

vi. What will be the value of β for a solid for which α has value of $2 \times 10^{-5}\ K^{-1}$?

(a) $2 \times 10^{-5}\ K^{-1}$ **(b) $6 \times 10^{-5}\ K^{-1}$ ✓**
(c) $8 \times 10^{-15}\ K^{-1}$ **(d)** $8 \times 10^{-5}\ K^{-1}$

vii. A large water reservoir keeps temperature of nearby land moderate due to:

(a) Low temperature of water **(b)** low specific heat of water
(c) less absorption of heat **(d) large specific heat of water ✓**

viii. Which of the following affects evaporation?

(a) Temperature **(b)** Surface area of the liquid
(c) wind **(d) all of the above ✓**

8.2 Why does heat flow from hot body to cold body?

Ans: Molecules of hot body have greater kinetic energy than the molecules of cold body. Therefore, fast moving molecules give their energy to cold body. So we can say that heat flows from hot body to the cold body.

8.3 Define the term heat and temperature. **(LHR 2013)**

Ans: Heat

Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature.

Temperature

Degree of coldness or hotness of the body is a measure of its temperature

8.4 What is meant by internal energy of a body?

Ans: The sum of kinetic energy and potential energy associated with the atoms, molecules and particles of a body is called the internal energy.

8.5 How does heating affect the motion of molecules of a gas?

Ans: Oh heating the gas, the motion of the molecules becomes faster. As a result average K.E and temperature of gas increases.

8.6 What is thermometer? Why mercury is preferred as thermometric substance?

Ans: The instrument which is used to measure the temperature is called a thermometer. Mercury is preferred as thermometric substance because

- It has high boiling point
- It has low melting point
- It does not wet glass
- Good conductor
- Opaque
- Has low heat capacity

8.7 Explain the volumetric thermal expansion.

Ans: See Q. 11 Long Question

8.8 Define specific heat. How would you find the specific heat of a solid?

Ans: See Q. 2 'the method of mixture is used to find the specific heat of any solid'.

8.9 Define and explain latent heat of fusion.

Ans: See Q. 6 Long Question

8.10 Define latent heat of vaporization.

Ans: See Q. 7 Long Question

8.11 What is meant by evaporation? On what factors the evaporation of a liquid depends? Explain how cooling is produced by evaporation?

Ans: See Q. 8 Long Question

Unit 8: Thermal Properties of Matter

Long Questions

8.2 THERMOMETER

Q.1 What is thermometer? Explain its different types.

Ans: "The instrument which is used to measure the temperature is called a thermometer"

Thermometric Substance

Some substances have property that changes with temperature. Substance that show change with temperature can be used as thermometric material. Common thermometers are generally made using some suitable liquid as thermometric material.

Properties of Thermometric Properties

A thermometric liquid should have the following properties:

- It should be visible
- It should have uniform thermal expansion
- It should have a low freezing point
- It should have high boiling point
- It should not wet glass
- It should be a good conductor of electricity
- It should have small specific heat capacity

Liquid – In – glass Thermometer

A liquid – in – glass thermometer has a bulb with a long capillary tube of uniform and fine bore. A suitable liquid is filled in the bulb. When the bulb contacts a hot object, the liquid in it expands and rises in the tube. The glass stem of a thermometer is thick and acts as a cylindrical lens. This makes it easy to see the liquid level in the glass tube.

Mercury Liquid – in – Glass Thermometer

Mercury freezes at -39 °C and boils at 357 °C. It has all the thermometric properties listed above. Thus mercury is one of the most suitable thermometric materials. Mercury – in – glass thermometers are widely used in laboratories, clinics and houses to measure temperatures in range from -10 °C to 150 °C.

Reference points

A thermometer has a scale on its stem. This scale has two fixed points.

Lower Fixed Point

The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice.

Upper Fixed Point

The upper fixed point is marked to show the position of liquid in the thermometer when it is placed in stem at standard pressure above boiling water.

Scales of Temperature

The distance between two reference points is divided in different divisions. A scale is marked on the thermometer. The temperature of the body in contact with the thermometer can be read on that scale.

Types of Temperature Scale

There are three types of temperature scale.

(i) Celsius scale or centigrade scale

(ii) Fahrenheit scale

(iii) Kelvin scale

Fahrenheit and centigrade or Celsius scales are used to measure temperatures in ordinary life while Kelvin scale is in practice for scientific purposes.

Celsius scale

On Celsius scale, for water the interval between lower and upper fixed point is divided into 100 equal divisions. The lower fixed point is marked as 0 °C and the upper fixed point is marked as 100 °C.

Fahrenheit scale

On Fahrenheit scale, the interval between lower and upper fixed points is divided into 180 equal divisions. The lower fixed point is marked as 32 °F and the upper fixed point is marked as 212 °F.

Kelvin scale

In SI units, the unit of temperature is Kelvin (K) and its scale is called Kelvin scale of temperature. The interval between the lower and upper fixed points is divided into 100 equal divisions. Thus a change in 1°C is equal to a change of 1 K. the lower fixed point on the scale corresponds to 273 K and the upper fixed point is referred as 373 K. The zero on this scale is called the absolute zero and is equal to – 273 °C.

Q.2 What is specific heat? Explain with examples and derive its mathematical formula.

Ans: "Specific heat of a substance is the amount of heat that is required to raise the temperature of 1 kg mass of that substance through 1K".

Explanation

Generally, when a body is heated, its temperature increases. Increase in the temperature of a body is found to be proportional to the amount of heat absorbed by it.

It has also been observed that the quantity of heat ΔQ required to raise the temperature ΔT of a body is proportional to the mass m of the body.

Thus $\Delta Q \propto m \Delta T$

or $\Delta Q = c\, m\, \Delta T$

Here ΔQ is the amount of heat absorbed by the body and c is the constant of proportionality called the specific heat capacity or simply specific heat.

So $$c = \frac{\Delta Q}{m\Delta T}$$

Unit

In SI units, mass m is measured in kilogram (kg), heat ΔQ is measured in joule (J) and temperature increases. ΔT is taken in Kelvin (K). So, SI unit of specific heat $Jkg^{-1}K^{-1}$.

Q.3 Explain the importance of large specific heat capacity of water.

Ans: Specific heat of water is 4200 $Jkg^{-1}K^{-1}$ and of dry soil is about 810 $Jkg^{-1}K^{-1}$. As a result the temperature of soil would increase five times more than the same mass of water by the same amount of heat.

Water has a large specific heat capacity. For this reason, it is very useful in storing and carrying thermal energy due to its high specific heat capacity.

Examples

(i) The temperature of land rises and falls more rapidly than that of the sea. Hence, the temperature variations from summer to winter are much smaller at places near the sea than land far away from the sea. So climate of the regions near sea shore, like Karachi, remains moderate.

(ii) The cooling system of the automobiles uses water to carry large amount of heat is produced by its engine due to which its temperature goes on increasing. The engine would cease unless it is not cooled down. Water circulating around the engine maintains the temperature. Water absorbs unwanted thermal energy of the engine and dissipates heat through its radiator.

(iii) In central heating systems hot water is used to carry thermal energy through pipes from boiler to radiators. Theses radiators are fixed inside the house at suitable places.

Heat Capacity

Q.4 Define heat capacity. Derive its mathematical formula and write down an activity to explain it.

Ans: Heat capacity of a body is the quantity of thermal energy absorbed by it for one Kelvin (1K) increases in its temperature.

Mathematical Form

Thus, if the temperature of a body increases through ΔT on adding ΔQ amount of heat, then its heat capacity will be $\Delta Q/\Delta T$. putting the value of ΔQ, we get

$$\text{Heat capacity} = \frac{\Delta Q}{\Delta T} = \frac{mc\Delta T}{\Delta T}$$

Heat capacity = mc

The above equation shows that heat capacity of a body is equal to the product of its mass of the body and its specific heat capacity.

Example

Heat capacity of 5 kg of water is (5 kg x 4200 $Jkg^{-1}K^{-1}$) 21000 Jkg^{-1}. That is 5 kg of water needs 21000 joules of heat for every 1 K rise in its temperature. Thus, larger is the quantity of a substance, larger will be its heat capacity.

8.4 CHANGE OF STATE

Q.5 Explain with an activity the change of state.

Matter can be changed from one state to another. For such a change to occur, thermal energy is added to or from a substance.

Activity

Take a beaker and place it over a stand. Put small pieces of ice in the beaker and suspend a thermometer in the beaker to measure the temperature of ice.

Now place a burner under the beaker. The ice will start melting. The temperature of the mixture containing ice and water will not increase above 0 °C until all the ice melts and we get water at 0° C is further heated, its temperature will begin to increase above 0° C as shown in figure.

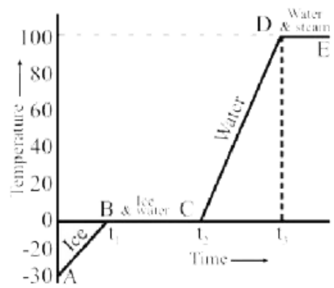

Figure 8.9: A graph of temperature and time showing change of state of ice into water and steam.

Part AB: On this portion of the curve, the temperature of ice increases from -30 °C to 0 °C.

Part BC: when the temperature of ice reaches 0 °C, the ice water mixture remains at this temperature until all the ice melts.

Part CD: The temperature of the substance gradually increases from 0 °C to 100 °C. the amount of energy so added is used up in increasing the temperature of water.

Part DE: At 100 °C water begins to boil and changes into steam. The temperature remains 100 °C until all the water changes into steam.

8.5 LATENT HEAT OF FUSION

Q.6 Define latent heat of fusion and write down its mathematical formula.

Ans: "Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in the temperature is called its latent heat of fusion".

Mathematical Formula

It is denoted by H_f.

$$H_f = \frac{\Delta Q_f}{m}$$

Or $\Delta Q_f = m\, H_f$

Latent Heat of Fusion of Ice

Ice changes at 0° C into water. Latent heat of fusion of ice is 3.36×10^5 Jkg^{-1}. That is; 3.36×10^5 joules heat is required to melt 1 kg of ice into water 0° C.

Experiment 8.1

Get a beaker, set it over a stand. Put small pieces of ice in it after hanging thermometer to note the temperature. Place a heat source under it and let the ice to melt. You will observe that temperature will not rise more than 0^0C until complete ice melts into water with a time gap.

The continued heat will rise temperature to 100^0C without repeat in time gap. Drawing graph, you can calculate the latent heat of fusion of ice with the data as given:

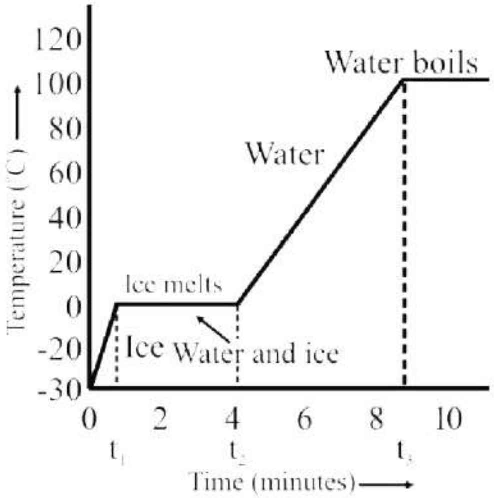

Figure 8.11: Temperature-time graph as ice changes into water that boils as heating continues.

Suppose the mass of ice $= m$

Measuring the time from the graph

Time taken by water to melt completely at 0° C $= t_f = t_2 - t_1 = 3.6$ minutes

Time taken by water to heat from 0°C to 100° C $= t_o = t_3 - t_2 = 4.6$ minutes

Specific heat of water $c = 4200\ JKg^{-1}\ K^{-1}$

Increase in the temperature of water $\Delta T = 100°\ C$

Heat required by water from 0° C to 100° C $= \Delta Q = ?$

As we know that

$$\Delta Q = m\, c\, \Delta T$$
$$= m \times 4200 \times 100$$
$$= m \times 4.2 \times 10^3 \times 10^2$$
$$= 4.2 \times 10^5 \times m \qquad JKg^{-1}$$

To raise the temperature of the water from 0° C to 100° C, ΔQ is given to water. So the heat absorption rate of water in beaker can be given by

Rate of absorbing heat $= \Delta Q/t_o$

Since heat absorption in time $t_f = \Delta Q_f = (\Delta Q \times t_f)/t_o$

$$= \Delta Q \times (t_f/t_o)$$

As we know that $\Delta Q_f = m \times H_f$

$$m \times H_f = 4.2 \times 10^5 \times m \times (t_f/t_o)$$
$$H_f = 4.2 \times 10^5 \times (t_f/t_o)$$

Putting the values of t_f and t_o which can be found though graph

$$H_f = 4.2 \times 10^5 \times (3.6/4.6)\ JKg^{-1}$$
$$H_f = 3.29 \times 10^5\ JKg^{-1}$$

The latent heat of fusion of ice (H_f) found for above experiment is 3.29×10^5 JKg^{-1} however actual value is 3.36×10^5 JKg^{-1}.

8.6 LATENT HEAT OF VAPORIZATION

Q.7 Define latent heat of vaporization. Write its mathematical formula.

Ans: "The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization"

Explanation

When heat is given to a liquid at its boiling point, its temperature remains constant. The heat energy given to liquid at its boiling point is used up in changing its state from liquid to gas without any increase in its temperature.

Mathematical Form

It is denoted by H_v

$$H_v = \frac{\Delta Q_v}{m}$$

OR $\Delta Q_v = m H_v$

Latent Heat of Vaporization of Water

When water is heated, it boils at 100 °C under standard pressure. Its temperature remains 100°C until it is changed into steam. Its latent heat of vaporization is 2.26 x 106 Jkg-1. That is; one kilogram of water requires 2.26×10^6 joule heat to change it completely into gas (steam) at its boiling point.

Experiment 8.2

Water in the breaker takes to change completely into steam at its boiling point 100°C

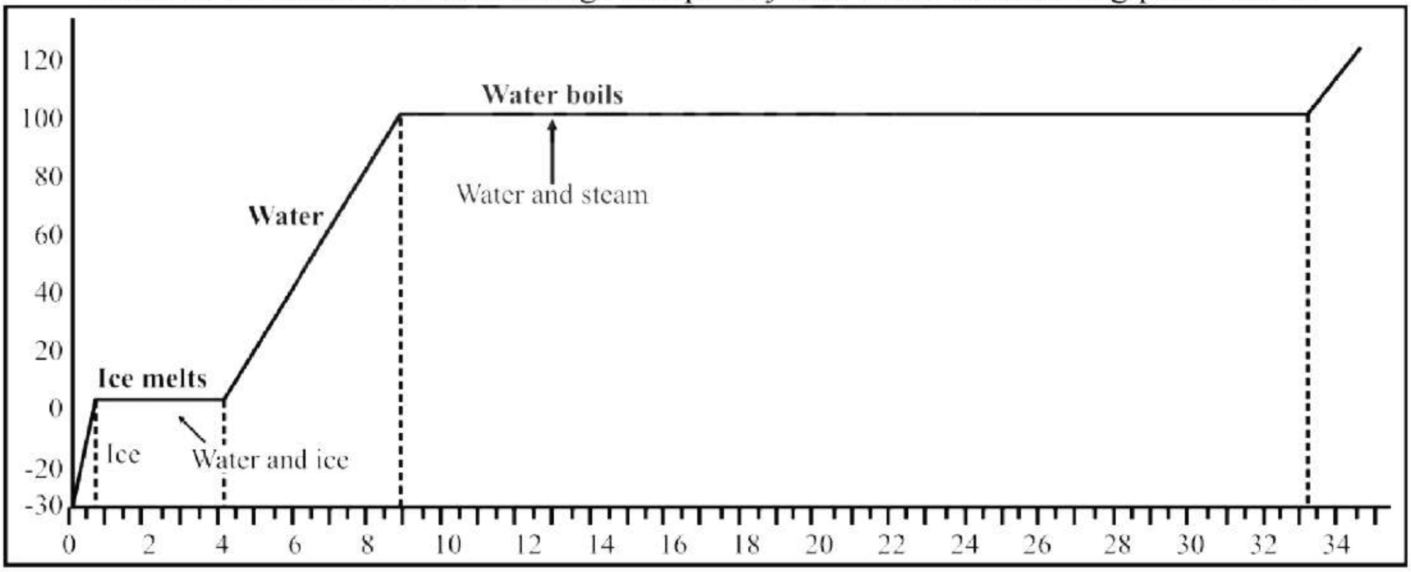

Figure: 8.12: Temperature-time graph as ice changes into water and water into steam on heating

Now take the boiling water of last experiment and heat till all water changes into steam. The time taken by boiled water to vaporize into steam is shown in graph. From graph, you can calculate the latent heat of vaporization of boiled water with the data as given:

Suppose: The mass of ice = m

Measuring the time from the graph

Time taken by water to heat from 0° C to 100° C = $t_o = t_3 - t_2$ = 4.6 minutes

Time taken by water to get changed into steam = $t_v = t_4 - t_3$ = 24.4 minutes

Specific heat of water $c = 4200\ JKg^{-1}\ K^{-1}$

Increase in the temperature of water $\Delta T = 100°\ C$

Heat required by water from 0° C to 100° C $= \Delta Q = m\,c\,\Delta T$

$= m \times 4200 \times 100$

$= m \times 4.2 \times 10^3 \times 10^2$

$= 4.2 \times 10^5 \times m \quad JKg^{-1}$

To raise the temperature of the water from 0° C to 100° C, ΔQ is given to water. So the heat absorption rate of water in beaker can be given by

Rate of absorbing heat $= \Delta Q/t_o$

Since heat absorption in time $t_v = \Delta Q_v = (\Delta Q \times t_v)/t_o$

$$= \Delta Q \times \left(\frac{t_v}{t_o}\right)$$

As we know that $\Delta Q_v = m \times H_v$

$$m \times H_v = 4.2 \times 10^5 \times m \times (t_v/t_o)$$

$$H_v = 4.2 \times 10^5 \times (t_v/t_o)$$

Putting the values of t_v and t_o which can be found though graph

$$H_f = 4.2 \times 10^5 \times (24.4/4.6)\ JKg^{-1}$$

$$H_f = 2.23 \times 10^6\ JKg^{-1}$$

The latent heat of vaporization of boiled water (H_v) found for above experiment is $2.23 \times 10^6\ JKg^{-1}$ however actual value is $2.26 \times 10^6\ JKg^{-1}$.

8.7 THE EVAPORATION

Q.8 Define evaporation. On what factor speed of evaporation depend? Explain.
(LHR 2016)

Ans: "Evaporation is the changing of a liquid into vapors (gaseous state) from the surface of the liquid without heating it".

Explanation

Take some water in a dish. The water in the dish will disappear after some time. It is because the molecules of water are in constant motion and possesses kinetic energy. Fast moving molecules escape out from the surface of water and goes into atmosphere.

Comparison of Boiling and Evaporation

Unlike boiling, evaporation takes place at all temperatures but only from the surface of a liquid. At boiling point, a liquid is changing into vapors not only from the surface but also within the liquid. These vapors are comes out of the boiling liquid as bubbles which breakdown on reaching the surface.

Example

Evaporation plays an important role in our daily life. We cloths dry up rapidly when spread.

Cooling Effect Produced by Evaporation

During evaporation fast moving molecules escape out from the surface of the liquid. Molecules that have lower kinetic energies are left behind. This lowers the average kinetic energy of the liquid molecules and the temperature of the liquid. Since temperature of a substance depends on the average kinetic energy of its molecules. Evaporation of perspiration helps to cool our bodies.

Dependence Factors

Evaporation takes place at all temperatures from the surface of a liquid. The rate of evaporation is affected by various factors.

Temperature

Why wet clothes dry up more quickly in summer than in winter? At higher temperature, more molecules of a liquid are moving with high velocities. Thus, more molecules escape from its surface. Thus, evaporation is faster at high temperature that at low temperature.

Surface Area

Why water evaporates faster when spread over large area? Large is the surface area of a liquid, greater number of molecules has the chance to escape from its surface.

Wind

Wind blowing over the surface of a liquid sweeps the liquid molecules that have just escaped out. This increases the chance for more liquid molecules to escape out.

Nature of the Liquid

Evaporation depends on the nature of the liquid. If we take spirit and water on our palm. As evaporation rate of spirit is greater than water, so we feel cooling effect due to evaporation of spirit.

8.8 THERMAL EXPANSION

Q.9 What is thermal expansion? Explain on the basis of kinetic molecular theory.

(LHR 2014)

Ans: Most of the substances solids, liquids and gases expand on heating and contract on cooling. Their thermal expansion and contractions are usually small and are not noticeable. However these expansions and contractions are important in our daily life.

Explanation on the basis of Kinetic Molecular Theory

The kinetic energy of the molecules of an object depends on its temperature. The molecules of a solid vibrate with large amplitude at high temperature than at low temperature. Thus, on heating, the amplitude of vibration of the atoms or molecules of an object increases. They push one another farther away as the amplitude of vibration increases. Thermal expansion results an increase in length, breadth and thickness of a substance.

Linear Thermal Expansion in Solids

Q.10 What is linear Expansion? On what factor it depend? Derive its mathematical formula.

Ans: "If a thin rod is heated, there is a prominent increase in its length as compared to its cross-sectional area. The expansion along length or in one dimension is called linear expansion".

Dependence

If we heat a metal rod the length of which is much larger than its thickness, then the increase in length depends on the following three factors:

(i) Length of thin rod.

(ii) Change in temperature.

(iii) Nature of material of the rod.

Mathematical form

Solids expand on heating and their expansion is nearly uniform over a wide range of temperature. Consider a metal rod of length L_o at certain temperature T_o. Let its length on heating to a temperature T becomes L. Thus

Increase in length of the rod $= \Delta L = L - L_o$

Increase in temperature $= \Delta T = T - T_o$

It is found that change in length ΔL of a solid is directly proportional to its original length L_o, and the change in temperature ΔT. that is;

$$\Delta L \propto L_o \Delta T$$

OR

$$\Delta L = \alpha L_o \Delta T$$

OR

$$L - L_o = \alpha L_o \Delta T$$

$$L = L_o (1 + \alpha \Delta T)$$

Coefficient of Linear Expansion

$$\alpha = \frac{\Delta L}{L_o\,\Delta T}$$

Where α is the proportionality constant called co-efficient of linear expansion which depends on the nature of the material of the rod and it can be defined as:

"The fractional increase in its length per Kelvin rise in temperature which has unit K^{-1}"

OR

"If a rod of one meter length is heated through a temperature difference of 1K then the change in the length of the rod is called the co-efficient of linear expansion which has unit K^{-1}".

Volume Thermal Expansion

Q.11 What is volume expansion? On what factors it depend? Derive its mathematical formula.

Ans: "Heating a block causes an increase in length, breadth and thickness, i.e., volume of the block increases that is known as volume expansion".

Volume of a solid also changes with the change in temperature and is called volume thermal expansion or cubical thermal expansion.

Dependence

If we heat a block then increase in volume of the block depends on the following three factors:

(i) Original volume of block.

(ii) Change in temperature.

(iii) Nature of material of the block.

Mathematical form

Consider a solid of initial volume V_o at certain temperature T_o. On heating the solid to a temperature T, let its volume becomes V, then

Increase in volume of a solid = $\Delta V = V - V_o$

And Change in temperature = $\Delta T = T - T_o$

Like linear expansion, the change in volume ΔV is found to be proportional to its original volume V_o and change in temperature ΔT. Thus

$$V - V_o \propto V_o$$

And $$V - V_o \propto \Delta T$$

$$V - V_o \propto V_o\,\Delta T$$

$$V - V_o = \beta V_o\,\Delta T$$

$$V = V_o + \beta V_o\,\Delta T$$

$$V = V_o(1 + \beta\,\Delta T)$$

Coefficient of Volume Expansion

Where β is the proportionality constant and is called the co-efficient of volume expansion.

$$\beta = \frac{\Delta V}{V_o\,\Delta T}$$

Thus, we can define the temperature coefficient of volume expansion as:

"The fractional change in its volume per Kelvin change in temperature".

OR

"If a block of one meter cube volume is heated through a temperature difference of 1K then the change in the volume of the block is called the co-efficient of linear expansion".

Its unit is also K^{-1}, but as compared to the co-efficient of linear expansion, it is three times greater.

$$\beta = 3\alpha$$

Consequences of Thermal Expansion

Q.12 Write down the consequences of thermal expansion.

Ans: The expansions of solids many damage bridges, railway tracks and roads as they are constantly subjected to temperature changes.

- Prevision is made during construction for expansion and contraction with temperature.
- Railway tracks buckled on a hot summer day due to expansion if gaps are not left between sections.
- Bridges made of steel girders also expands during the day and contract during night. They will bend if their ends are fixed. To allow thermal expansion, one end is fixed while the other one of the girder rests on rollers in the gap left for expansion. Overhead transmission lines are also given a certain amount of sag so that they contract in winter without snapping.

Applications of Thermal Expansion

Q.13 Write down the applications of thermal expansion.

Ans: Thermal expansion is used in our daily life. In thermometers, thermal expansion is used in temperature measurements.

- To open the cap of a bottle that is tight enough, immerse it in hot water for a minute or so. Metal cap expands and becomes loose. It would now be easy to turn it to open.
- To join steel plates tightly together, red hot rivets are forced through holes in the plates as shown in figure. The end of hot rivet is then hammered. On cooling, the rivets contracts and bring the plates tightly griped.
- Iron rims are fixed on wooden wheels of carts. Iron rims are heated. Thermal expansion allows them to slip over the wooden wheel. Water is poured on it to cool. The rim contracts and becomes tight over the wheel.

Bimetal Strip (Thermostat)

A bimetal strip consists of two thin strips of different metals such as brass and iron joined together as shown in figure. On heating the strip, brass expands more than iron. This unequal expansion causes bending of the strip as shown in figure.

Usage

Bimetal strips are used for various purposes.

- Bimetal thermometers are used to measure temperature especially in furnaces and ovens.
- Bimetal strips are also used in thermo states.
- Bimetal thermo state switch is used to control the temperature of heater coil in an electric iron.

Thermal Expansion of Liquids

Q.14 Explain the thermal expansion of liquid.

Ans: The molecules of liquids are free to move in all directions within the liquid. On heating a liquid, the average amplitude of vibration of its molecules increases. The molecules push each other and need more space to occupy. This accounts for the expansion of the liquid when heated. The thermal expansion in liquids is greater than solids due to the weak forces between their molecules. Therefore, the coefficient of volume expansion of liquids is greater than solids.

No Definite Shape of Liquids

Liquids have no definite shape of their own. A liquid always attains shape of the container in which it is poured. Therefore, when a liquid is heated, both liquid and the container undergo a change in their volume.

Activity

Take a long-necked flask. Fill it with some colored liquid up to mark A on its neck as shown in figure. Now start heating the flask from bottom. The liquid level first falls to B and then rises to C.

Relation between expansions

We observe that there are two types of expansions appear as a result of heating a liquid in any container.

(i) Real expansion

(ii) Apparent expansion

In the given figure, real expansion is from B to C whereas A to C is apparent expansion. AB shows the expansion of the flask, whereas BC represents the real expansion of the liquid. Real expansion of the liquid is equal to the volume difference between A and C in addition to the volume expansion of the flask.

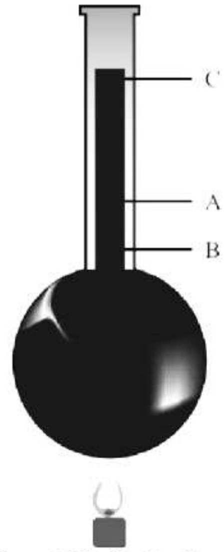

Figure 8.21: Real and apparen expansion of liquid.

It can be seen that real expansion is comparatively greater than apparent expansion and they are related as follows:

Real expansion of liquid = Apparent expansion of liquid + Expansion of the flask

BC = AC + AB

The expansion of the volume of a liquid taking into consideration the expansion of the container also, is called the real expansion of the liquid.

Coefficients of volume expansions

The real rate of volume expansion β_r of a liquid is defined as the actual change in unit volume of a liquid for 1K (or 1 °C) rise in its temperature. The real rate of volume expansion β_r is always greater than the rate of volume expansion β_a by an amount equal to the rate of volume expansion of the container β_g.

Thus $\beta_r = \beta_a + \beta_g$

It should be noted that different liquids have different coefficients of volume expansion.

Coefficients of liquid expansion

In accordance with the apparent and real expansions of the liquids, their co-efficient of expansion are also measured in two ways:

(i) Coefficient of apparent expansion

(ii) Coefficient of real expansion

Unit 8: Thermal Properties of Matter

Multiple Choice Questions

1. **All the bodies expand ---------- on heating:**
   (a) Variable **(b)** Constantly
   (c) Uniformly **(d)** All of them
2. **Temperature is the:**
   (a) Mass contained by the body **(b)** Force of the molecules of body
   (c) Degree of hotness or coldness of the body **(d)** none of above
3. **The SI unit of temperature is:**
   (a) ^{o}C **(b)** ^{o}F
   (c) K **(d)** ^{o}K
4. **Temperature of 30 ^{o}C in Fahrenheit is:**
   (a) 86 ^{o}F **(b)** 80 ^{o}F
   (c) 30 ^{o}F **(d)** 90 ^{o}F
5. **Human normal body temperature of 37 ^{o}C in Fahrenheit is:**
   (a) 98. 6 ^{o}F **(b)** 98 ^{o}F
   (c) 100 ^{o}F **(d)** None of above
6. **Boiling point of water in Fahrenheit is:**
   (a) 100 ^{o}F **(b)** 273 ^{o}F
   (c) 212 ^{o}F **(d)** 373 ^{o}F
7. **Celsius equivalent of 0K is:**
   (a) -273 ^{o}C **(b)** -459.4 ^{o}C
   (c) 0 ^{o}C **(d)** 100 ^{o}C
8. **Fahrenheit equivalent of 0K is:**
   (a) -273 ^{o}F **(b)** -459.4 ^{o}F
   (c) 0 ^{o}F **(d)** 100 ^{o}F
9. **Heat is a type of ----------- energy:**
   (a) Kinetic **(b)** Potential
   (c) Mechanical **(d)** None of above
10. **Linear expansion of a rod occur along ------------- dimension (s):**
    (a) One **(b)** Two
    (c) Three **(d)** All
11. **The characteristic of unequal expansion of different metals is employed in a device known as:**
    (a) Thermometer **(b)** Burner
    (c) Calorimeter **(d)** Thermostat
12. **Linear expansion depends on:**
    (a) Length of rod **(b)** Change in temperature
    (c) Nature of material of rod **(d)** All of above
13. **Thermostat works on the principle of:**
    (a) Unequal expansion of solids **(b)** Pascal's law
    (c) Anomalous expansion of water **(d)** Vaporization
14. **Thermostat is used in:**
    (a) Electric iron **(b)** Refrigerator
    (c) Fire alarm **(d)** All of above
15. **SI unit of Coefficient of linear & volume expansion is:**
    (a) m **(b)** K

(c) K^{-1} **(d)** °C

16. **Volume expansion depends on:**
(a) Volume of block **(b)** Change in temperature
(c) Nature of material of block **(d)** All of above

17. **β = -------**
(a) α **(b)** 2α
(c) 3α **(d)** 5α

18. **There are ------ type (s) of expansion (s) take place in a liquid filled in a container:**
(a) One **(b)** Two
(c) Three **(d)** Four

19. **The liquid (s) used in thermometers is (are):**
(a) Mercury **(b)** Alcohol
(c) Water **(d)** Both a & b

20. **Ice is a (an):**
(a) Good conductor **(b)** Bad conductor
(c) Perfect Conductor **(d)** None

21. **The quantity of heat that causes 1K change in temperature in a substance of mass 1 Kg is called:**
(a) Specific heat **(b)** Latent heat
(c) Heat of exchange **(d)** None of above

22. **Unit of specific heat is:**
(a) $Jkg^{-1}K$ **(b)** $JkgK^{-1}$
(c) $Jkg^{-1}K^{-1}$ **(d)** J

23. **Which of the following has highest specific heat?**
(a) Water **(b)** Ice
(c) Mercury **(d)** Alcohol

24. **Specific heat of water is:** **(GRW 2013, 2014)**
(a) 2100 $Jkg^{-1}K^{-1}$ **(b)** 2500 $Jkg^{-1}K^{-1}$
(c) 3200 $Jkg^{-1}K^{-1}$ **(d)** 4200 $Jkg^{-1}K^{-1}$

25. **Climate of regions near sea shore remains moderate due to:**
(a) Greater specific heat of water **(b)** Less specific heat of water
(c) Low freezing point of water **(d)** High boiling point of water

26. **Cause of land and sea breeze is:**
(a) Greater specific heat of water **(b)** Less specific heat of water
(c) Low freezing point of water **(d)** High boiling point of water

27. **The device used to measure of the specific heat of an object is:**
(a) Thermometer **(b)** Burner
(c) Calorimeter **(d)** Thermostat

28. **Quantity of heat that changes one kilogram of a of solid into liquid is called:**
(a) Specific heat **(b)** Latent heat of fusion
(c) Latent heat of vaporization **(d)** All of above

29. **Quantity of heat that changes one kilogram of a of liquid into gas is called:**
(a) Specific heat **(b)** Latent heat of fusion
(c) Latent heat of vaporization **(d)** All of above

30. **Unit of latent heat is:**
(a) $Jkg^{-1}K$ **(b)** Jkg
(c) J **(d)** Jkg^{-1}

31. **Latent heat of fusion of ice is:**

(a) 2,260,000 Jkg^{-1} **(b)** 336,000 Jkg^{-1}

(c) 3,260,000 Jkg^{-1} **(d)** None of above

32. Latent heat of vaporization of water is:

(a) 2,260,000 Jkg^{-1} **(b)** 336,000 Jkg^{-1}

(c) 3,260,000 Jkg^{-1} **(d)** None of above

ANSWER KEY

Q.No	Ans	Q.No	Ans	Q.No	Ans	Q.No	Ans
1	c	11	d	21	a	31	b
2	c	12	d	22	c	32	a
3	c	13	a	23	a		
4	a	14	d	24	d		
5	a	15	c	25	a		
6	c	16	d	26	a		
7	a	17	c	27	c		
8	b	18	c	28	b		
9	a	19	d	29	c		
10	a	20	b	30	d		

Last Updated: September 2020

Report any mistake at freeilm786@gmail.com

Unit 8: Thermal Properties of Matter

Problems

8.1 Temperature of the water in beaker is 50^0 C. What is its value in Fahrenheit?

Given Data

Temperature in Celsius = $T_c = 50^0$ C

Required

Temperature in Fahrenheit = T_f = ?

Solution

As we know that

$$F = \frac{9}{5}C + 32$$

By putting the values, we have

$$\frac{9}{5} \times 50 + 32$$

$$F = 90 + 32$$

$$F = 122\ ^oF$$

Result

Temperature in Fahrenheit = T_f = 122 °F

8.2 Normal human body temperature is 98.6^0 F. Convert it into Celsius and Kelvin scale.
(GRW 2013, LHR 2013, 2015)

Given Data

Normal human Temperature in Fahrenheit = $T_f = 98.6^0$ F

Required

Temperature in Celsius = T_c = ?
Temperature in Kelvin = T_K = ?

Solution

As we know that

$$C = \frac{5}{9}(F - 32)$$

By putting the values, we have

$$C = \frac{5}{9}(98.6 - 32)$$

$$C = \frac{5}{9}(66.6)$$

$$C = 37\ ^oC$$

As we know that

$$T_K = C + 273$$

By putting the values, we have

$$T_K = 37 + 273 = 310\ K$$

$$T_K = 310\ K$$

Result

Temperature in Celsius = T_c = 37 °C
Temperature in Kelvin = T_k = 310 K

8.3 Calculate the increase in length of an aluminium bar of 2m long when heated from 0^0 C to 20^0 C. If the thermal coefficient of linear expansion of aluminum is 2.5×10^{-5} K^{-1}.

Given Data

Length of aluminum bar = $L_1 = 2$ m

Initial temperature = $T_1 = 0°C = (0 + 273)$ K = 273 K

Final temperature = $T_2 = 20°C = (20 + 273)$ K = 293 K

Coefficient of linear expansion of aluminum = $\alpha = 2.5 \times 10^{-5}$ K^{-1}

Required

Increase in length = $L - L_o = ?$

Solution

As we know that

$$L - L_o = \alpha L_o (T_2 - T_1)$$

By putting the values, we have

$$L - L_o = 2.5 \times 10^{-5} \times 2 \times (293 - 273)$$

$$L - L_o = 5 \times 10^{-5} (20)$$

$$L - L_o = 100 \times 10^{-5}$$

$$L - L_o = 1 \times 10^{-3} \text{ m} = 0.1 \text{ cm} = 1 \text{ mm}$$

Result

Increase in length = $L - L_o = 1 \times 10^{-3}$ m = 0.1 cm = 1 mm

8.4 A balloon contains 1.2 m^3 of air at 15^0 C. Find its volume at 40^0 C. Thermal coefficient of volume expansion of air is 3.67×10^{-3} K^{-1}.

Given Data

Initial volume of air in balloon = $V_1 = 1.2$ m^3

Initial temperature = $T_1 = 15^0$ C = (15 + 273) K = 288 K

Final temperature = $T_2 = 40^0$ C = (40 + 273) K = 313 K

Coefficient of volume expansion = $\beta = 3.67 \times 10^{-3}$ K^{-1}

Required

Final volume of gas = $V_2 = ?$

Solution

As we know that

$$V = V_o (1 + \beta(T_2 - T_1))$$

By putting the values, we have

$$V = 1.2 (1 + 3.67 \times 10^{-3} \times (313 - 288))$$

$$V = 1.2 (1 + 3.67 \times 10^{-3} (25))$$

$$V = 1.2 (1 + 91.75 \times 10^{-3})$$

$$V = 1.2 (1 + 0.091)$$

$$V = 1.2 + 0.108 = 1.308 = 1.3 \text{ m}^3$$

Result

Final volume of gas = $V_2 = 1.3$ m^3

8.5 How much heat is required to increase the temperature of 0.5 kg of water from 10^0 C to 65^0 C. (LHR 2014 GRW 2015)

Given Data

Mass of water = m = 0.5 kg

Initial temperature = $T_1 = 10^0$ C

Final temperature = $T_2 = 65^0$ C

Change in Temperature

$$\Delta T = T_2 - T_1$$
$$= (65-10)^{\circ} C$$
$$= 55^{\circ} C$$
$$= 55K$$

Required

Heat required = Q =?

Solution

As we know that

$$\Delta Q = mc\Delta T$$

By putting the values, we have

$$\Delta Q = 0.5 \times 4200 \times 55$$
$$\Delta Q = 115500 \text{ J}$$

Result

Heat required = Q = 115500 J

8.6 An electric heater supplies heat at the rate of 1000 joules per second. How much time is required to raise the temperature of 200 g of water from 20^0 C to 90^0 C?

Given Data

Rate of heat supplied by heat = P = 1000 Js^{-1}

Mass of water = m = 200 g = 0.2 kg

Specific heat of water = c = 4200J

Initial temperature = $T_1 = 20^0$ C

Final temperature = $T_2 = 90^0$ C

Change in temperature = $\Delta T = 90 - 20 = 70^{\circ}$ C = 70K

Required

Heat required = Q = ?

Time = t = ?

Solution

As we know that

$$Q = cm\,\Delta T$$
$$Q = 0.2 \times 4200 \times 70$$
$$Q = 58800 \text{ J}$$

As we also know that

$$P \times t = Q$$
$$t = Q/P$$
$$t = 588000/1000$$
$$t = 58.8 \text{ s}$$

Result

Heat required = Q = 58800 J

Time taken = t = 58.8 s

8.7 How much ice will melt by 50000 J of heat? Latent heat of fusion of (GRW 2013, 14)
ice = 336000 Jkg^{-1}.

Given Data

Heat supplied to ice = ΔQ_f = 50000 J

Latent heat of fusion of ice = H_f = 336000 Jkg^{-1}

Required

Mass of ice = m = ?

Solution

As we know that

$$\Delta Q = m \times H_f$$

So $$m = \frac{\Delta Q}{H_f}$$

By putting the values, we have

$$m = \frac{50000}{336000}$$

$$m = 0.15 \text{ kg} = 150 \text{ g}$$

Result

Mass of ice = m = 0.15 kg = 150 g

8.8 Find the quantity of heat needed to melt 100 g of ice at -10^0 C to 10^0 C.

Given Data

Mass of ice = m = 100 g = 0.1 kg

Specific heat of ice = 2100 $JKg^{-1}K^{-1}$

Specific heat of water = 4200 $JKg^{-1}K^{-1}$

Latent heat of fusion of ice = 336000 $JKg^{-1}K^{-1}$

Initial temperature of ice = T_1 = -10^0 C

Final temperature = T_2 = 10^0 C

Required

Heat required to raise the temperature of ice from –10°C to 10°C = Q = ?

Solution

Step-I Heat required to raise the temperature of ice from –10°C to 0°C = ΔQ_1 = ?

$T_1 = -10°C$

$T_2 = 0°C$

$\Delta T = 0°C-(-10)°C = 10°C = 10 \text{ K}$

$\Delta Q = cm\Delta T$

$\Delta Q_1 = 2100 \times 0.1 \times 10$

$\Delta Q_1 = 2100 \text{ J}$

Step-II Heat required to convert ice at 0°C into water at 0°C = ΔQ_2 =?

We know that

$\Delta Q = mL_f$

$\Delta Q_2 = 0.1 \times 336000$

$\Delta Q_2 = 33600 \text{ J}$

Step-III

Heat required to raise temperature water from 0°C to 10°C = ΔQ_3 =?

T1 = 0°C

T2 = 10°C

$\Delta T = 10°C - 0°C = 10°C = 10K$

We know that

$\Delta Q = cm\Delta T$

$\Delta Q_3 = 4200 \times 0.1 \times 10$

$\Delta Q_3 = 4200 \text{ J}$

Total heat required = $Q = \Delta Q_1 + \Delta Q_2 + \Delta Q_3$

$Q = 2100+33600+4200$

$Q = 39900 \text{ J}$

Result

Heat required = Q = 39900 J

8.9 How much heat is required to change 100 g of water at 100^0 C into steam?

(LHR 2013, 2015)

Given Data

Mass of water = m = 100 g = 0.1 kg

Temperature of water = T_1 = 100^0 C

Temperature of steam = T_2 = 100^0 C

Latent heat of vaporization of water = $H_v = 2.26 \times 10^6 \text{ Jkg}^{-1}$

Required

Heat required = Q_v = ?

Solution

$Q_v = m \times H_v$

$Q_v = 0.1 \times 2.26 \times 10^6 \text{ J}$

$Q_v = 2.26 \times 10^5 \text{ J}$

Result

Heat required = $Q_v = 2.26 \times 10^5$ J

8.10 Find the temperature of water after passing 5 g of steam at 100^0 C through 500 g of water at 10^0 C.

Given Data

Mass of water = m_1 = 500 g = 0.5 kg

Mass of steam = m_2 = 5 g = 0.005 kg

Temperature of water = T_1 = 10^0 C

Temperature of steam = T_2 = 100^0 C

Specific heat of water = c = 4200 $\text{Jkg}^{-1}\text{K}^{-1}$

Latent heat of vaporization of vaporization = H_v = 2.26 x 106 Jkg^{-1}

Required

Final temperature of water = T = ?

Solution

According to law of heat exchange

Heat lost by steam = Heat gain by water

$mH_v + cm\Delta T = cm\Delta T$

$(0.005)(2.26\times10^6) + (4200)(0.005)(100-T) = (4200)(0.5)(T-10)$

$11300+21(100-T) = 2100(T-10)$

$11300+2100-21T = 2100T-21000$

$11300+2100+21000 = 2100T+21T$

$344400 = 2121T$

$$T = \frac{34400}{2121}$$

$T = 16.2°C$

Result

Final temperature of water = T = 16.2°C

Unit 9: Transfer of Heat

Textbook Exercise Questions

9.1 Encircle the correct answer from the given choices.

1. In solids, heat is transferred by: **(LHR 2015)**
(a) Radiation **(b) conduction ✓**
(c) convection (d) absorption

2. What happens to the thermal conductivity of a wall if its thickness is doubled? **(GRW 2015)**
(a) Becomes double (b) remains the same
(c) Becomes half ✓ (d) becomes one forth

3. Metals are good conductor of heat due to the:
(a) Free electrons ✓ (b) big size of their molecules
(c) small size of their molecules (d) rapid vibration of their atoms

4. In gases, heat is mainly transferred by: **(LHR 2015)**
(a) Molecular collision (b) conduction
(c) convection ✓ (d) radiation

5. Convection of heat is the process of heat transfer due to the _________ of the molecules:
(a) Random motion (b) downward movement
(c) upward movement **(d) free movement ✓**

6. False ceiling is done to: **(LHR 2016)**
(a) Lower the height of ceiling (b) keep the roof clean
(c) cool the room **(d) insulate the ceiling ✓**

7. Rooms are heated using gas heaters by: **(GRW 2016)**
(a) Conduction only **(b) convection and radiation ✓**
(c) Radiation only (d) convection only

8. Land breeze blows from: **(LHR 2016)**
(a) See to land during night (b) sea to land during the day
(c) Land to sea during night ✓ (d) land to sea during the day

9. Which of the following is a good radiator of heat?
(a) A shining silvered surface **(b) A dull black surface ✓**
(c) A white surface (d) A green colored surface

10. Styrofoam is a:
(a) Conductor (b) Semiconductor
(c) Bad conductor ✓ (d) None of them

11. Unit of thermal conductivity is:
(a) $W\ m^{-1}\ K^{-1}$ ✓ (b) $W\ m^{-1}\ K^{-2}$
(c) $W\ m^{-2}\ K^{-1}$ (d) $W\ m^{2}\ K^{-1}$

9.2 Why metals are good conductors of electricity? (GRW2013, 2014, 2016)

Ans. Metals have free electrons. These free electrons move with very high velocities within the metal objects. They carry energy at a very fast rate from hot to cold parts of the objects as they move, that is why metal are good conductors of heat.

9.3 Explain why?

(a) A metal feels colder to touch than wood kept in a cold place?

Conductors have good conduction property. So by touching cold conductors, there is a rapid transfer of heat from our hand to cold conductor and it feels colder. As wood is a bad conductor, so transfer of heat from our hand to wood is very low. Due to this reason, we feel less cold.

(b) Land breeze blows from land towards sea?

At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the cold air from the land begins to move towards the sea.

(c) Double walled glass vessel is used in thermos flask?

A double walled glass is used to prevent the flow of heat due to conduction and convetion thorugh the vacuum between double walls of vessel.

(d) Desserts soon get hot during the day and soon get cold after sunset.

As the specific heat of sand is low, so it absorbs the heat more quickly and gets hot in day. In night, it releases heat more quickly and become cold quickly after sunset.

9.4 Why conduction of heat does not take place in gases? (GRW 2015)

Ans: Gases are poor conductor of heat because gases do not have fee electrons. Furture more for conduction molecules should be close while in gases molecules have vast spaces. That why gases do not undergo conduction.

9.5 What measures do you suggest to conserve energy in house? (LHR 2016)

Ans: To conserve energy in our house, following measure may be taken:

- Hot water tanks are insulated by plastic or foam lagging
- Wall cavities are filled with plastic foam or wool
- Ceiling of room is covered by insulating materials (false ceiling)
- Double glazed window panes are used, these windows panes have air between glass sheets that provides good insulation

9.6 Why transfer of heat in fluids takes place by convection? (GRW 2015)

Ans: Liquids and gases are poor conductors of heat due to large distances amoung their molecules. However, heat is transferred through fluids (liquids or gases) by a method called convection. Heat transfer of heat in fluids takes place by convection because movement of molecules is easy in fluids.

9.7 What is meant by convection current? (LHR 2013, GRW 2014, 2015)

Ans: Gases also expand on heating, thus convection currents are easily set up due to the differences in the densities of air at various parts in the atmosphere.

Example

Convection currents set up by electric, gas or coal heaters help to warm our homes and offices.

9.8 Suggest a simple activity to show convection of heat in gases not given in the book.

Ans: In summer, the intense radiations of sun warm the surface of Earth. The air near the surface is also heated and expands. Its density decreases due to increase of volume and it rises up. A colder air comes to fill this gap, due to which conventional currents of air are produced.

9.9 How does heat reach us from the sun?

Ans: Heat reaches us neither by conduction nor by convection, because the space between the Sun and Earth's atmosphere is empty. Heat reaches us through a mode called radiations (light waves) from the sun.

9.10 How various surfaces can be compared by Leslie cube?

Ans: Different sides of Leslie cube are made different in nature. So transfer of heat from different sides of the cube is different. So, various surfaces can be compared by Leslie cube. A leslie cube is a metal box having faces as follows:

- A shining silved surface
- A dull black surface
- A White surface
- A coloured surface

9.11 What is greenhouse effect? (LHR 2015, GRW 2016)

Ans: Glass and transparent polythene sheets allow radiations of short wavelength to pass through easily but not long wavelengths (infrared) of thermal radiations. Thus, greenhouse becomes a heat trap. Radiations from the sun pass easily through glass and warms up the objects in a greenhouse.

9.12 Explain the impact of green-house effect in global warming.

Ans: Earth's atmosphere contains carbon dioxide and water vapours. It causes greenhouse effect and thus maintains the temperature of the Earth. During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to greenhouse effect. This Phenomenon is known as global warming.

Unit 9: Transfer of Heat

Long Questions

9.2 CONDUCTION

Q.No.1 What is Conduction? Explain the process and write down it usage in our daily life.

Ans: "The mode of transfer of heat by vibrating atoms and free electrons in solids from hot to cold parts of a body is called conduction of heat".

OR

"Conduction is the process in which heat is transmitted from one body to another by the interaction of atoms and electrons".

Conduction Process

In solids, atoms and molecules are packed close together. They continue to vibrate about their mean position. When one end of the solid is heated then the atoms or molecules present at that end begin to vibrate more rapidly. They also collide with their neighboring atoms or molecules. In doing so, they pass some of their energy to neighboring atoms or molecules during collisions with them with the increase in their vibrations. These atoms and molecules in turn pass on a part of the energy to their neighboring particles. In this way some heat reaches the other parts of the solid. This is slow process and very small transfer of heat takes place from hot to cold parts in solids.

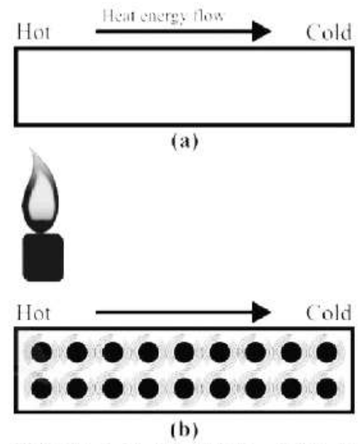

Figure 9.2: In solids, heat is transferred from one part to other parts from atoms to atoms or molecules to molecules due to collisions.

Speed of conduction in metals and non – metals

Metals have free electrons as shown in figure. These free electrons move with very high velocities within the metal objects. They carry energy at a very fast rate from hot to cold parts of the objects as they move. Thus, heat reaches the cold parts of the metal objects from its hot part much more quickly than non-metals.

Usage in household crockery

The handle of metal spoon held in hot water soon gets warm. But in case of wooden spoon handle does not get warm. Both the materials behave differently regarding the transfer of heat. Both metals and non-metals conduct heat. Metal are gradually better conductors than non-metals.

Q.No.2 On what factors conduction of heat depend? And define thermal conductivity. (GRW 2015)

Ans: Conduction of heat occurs at different rates in different materials. In metals, heat flows rapidly as compared to insulators such as wood or rubber. Consider a solid block. One of its two opposite faces each of cross – sectional area A is heated to a temperature T_1. Heat Q flows along its length L to opposite face at temperature T_2 in t seconds.

The amount of heat that flows in unit time is called the rate of flow of heat.

Thus Rate of flow of heat $= \frac{Q}{t}$

Dependence

It is observed that the rate at which heat flows through a solid object depends upon various factors.

- Cross sectional area of the solid
- Length of the solid
- Temperature difference between ends

Cross Sectional Area of the Solid

Larger cross sectional area A of a solid contains larger number of molecules and free electrons on each layer parallel to its cross sectional area and hence greater will be the rate of flow of heat through the solid.

Thus Rate of flow of heat $\frac{Q}{t} \propto A$

Length of the Solid

Larger is the length between the hot and cold ends of the solid, more time it will take to conduct heat to the colder end and smaller will be the rate of flow of heat.

Thus Rate of flow of heat $= \frac{Q}{t} \propto \frac{1}{L}$

Temperature Difference between Ends

Greater is the temperature difference $T_1 - T_2$ between the hot and cold faces of the solid, greater will be the rate of flow of heat.

Thus Rate of flow of heat $\frac{Q}{T} \propto (T_1 - T_2)$

Combining above factors, we get

$$\frac{Q}{t} \propto \frac{A(T_1 - T_2)}{L}$$

Rate of flow of heat $$\frac{Q}{t} = \frac{k\,A(T_1 - T_2)}{L}$$

Thermal Conductivity

Here k is the proportionality constant called thermal conductivity of the solid. Its value depends on the nature of the substance and it is different for different materials. Value of k can be found as:

$$k = \frac{Q}{t} \times \frac{L}{A}(T_1 - T_2)$$

The thermal conductivity of the substance can be defined as:

"The rate of flow of heat across the opposite faces of a meter cube of a substance maintained at a temperature difference of one Kelvin is called the thermal conductivity of that substance"

Use of Conductors and Non-Conductors **(LHR 2015)**

Q.No.3 Write down the uses of conductors and non – conductors.

Ans: In houses, good thermal insulation means lower consumption of fuel. For this, following measures may be taken to save energy.

- Hot water tanks are insulated by plastic or foam lagging
- Wall cavities are filled with plastic foam or wool

- Ceiling of room is covered by insulating materials (false ceiling)
- Double glazed window panes are used. These window panes have air between glass sheets that provides good insulation.
- Good conductors are used when quick transfer of heat is required through a body. Thus cookers, cooking plate, boiler, radiators and condensers of refrigerators etc. are made of metals such as aluminum or copper. Similarly metal boxes are used for making ice, ice cream etc.
- Insulators or bad – conductors are used in utensils such as handles of sauce – pans, hot plates, spoons etc. They are made of wood or plastic. Air is one of the bad conductors or good insulator. That is why cavity walls i.e. two walls separated by an air space and double glazed windows keep the houses warm in winter and cool in summer. Materials which trap air i.e. wool, felt, fur, feathers, polystyrene, and fiber glass are also bad conductors. Some of these materials are used for laggings to refrigerators, walls and roofs of houses. Woolen cloth is used to make warm winter clothes.

9.3 CONVECTION

Q.No.4 What is convection? Explain the process.

Ans: "Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection".

Liquids and gases are poor conductors of heat. However, heat is transferred through fluids (liquids or gases) by another method called convection.

Process

A liquid or gas becomes lighter (less dens) as it expands on heating. Hot liquid or gas from the surroundings fills the place which in turns is heated up. In this way, all fluid is heated up. Therefore, transfer of heat through fluids takes place by the actual movement of heated molecules from hot to cold parts of the fluid.

Experiment

Get a two-third water filled beaker and heat it by using burner. Pour 2 to 3 drops of $KMnO_4$. The colour start appearing first upward, then flow downward showing a path of liquid current. You will note that the liquid current will be disappeared on displacing the burner, as heat lift up the water making it light however the cold water tend to move down on getting denser.

Convection Currents in Air **(LHR 2013, 2014, 2015)**

Q.No.5 What do you know about convection currents in Air? How land and sea breeze blow?

Ans: Gases also expand on heating, thus convection currents are easily set up due to the differences in the densities of air at various parts in the atmosphere.

Uses of Convection currents

- Convection currents set up by electric, gas or coal heaters help to warm our homes and offices.
- Central heating systems in buildings work on the same principle of convection.
- The day –to– day temperature changes in the atmosphere result from the circulation or warm or cold air that travels across the region. Land and sea breezes are also examples of convection currents.

Land and Sea Breezes

Land and sea breezes are the result of convection.

Sea Breeze

On a hot day, the temperature of the land increases more quickly than the sea. It is because the specific heat of land is much smaller as compared to water. The air above land gets hot and rises up. Cold air from the sea begins to move towards the land. It is called sea breeze.

Land Breeze

At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the cold air from the land begins to move towards the sea. It is called land breeze.

Gliding (LHR 2014, GRW 2015)

Q.No.6 What is Gliding? And what do you know about birds gliding?

Ans: A glider looks like a small aeroplane without engine. Glider pilots use upward movement of hot air current due to convection of heat. These rising currents of hot air are called thermals. Gliders ride over these thermals. The upward movement of air currents in thermals helps them to stay in air for a long period.

Birds Gliding

The birds stretch out their wings and circle in these thermals. The upward movement of air helps birds to climb up with it. Eagles, hawks and vultures are expert thermal climbers. After getting a free lift, birds are able to fly for hours without flapping their wings. They glide from one thermal to another, and thus travel through large distances and hardly need to flap their wings.

9.4 RADIATION

Q.No.7 Define Radiation. How does heat reach us from the sun? Explain Radiation.

Radiation

Radiation is the mode of transfer of heat from one place to another in the form of waves called Electromagnetic waves.

Energy from Sun

Our sun is the major source of heat energy. Heat reaches us neither by conduction nor by convection, because the space between the Sun and Earth's atmosphere is empty. This is a third mode called radiation by which heat travels from one place to another. It is through radiations that heat reaches us from the sun.

Example (Heat from Fireplace)

Heat does not reach us by conduction through air from a fireplace because air is a poor conductor of heat. Heat does not reach us by convection because the air getting heat from the fireplace does not move in all directions. Hot air moves upward from the fireplace. Heat from the fireplace reaches us directly by a different process in the form of waves called radiation. A sheet of paper or cardboard kept in the path stop these waves to reach us.

Dependence of Rate of Radiation

Radiations are emitted by all bodies. The rate at which radiations are emitted depends upon various factors such as

- Color and texture of the surface
- Surface temperature

- Surface area

Heat absorbing and Radiating

All the objects, lying inside a room including the walls, roof and floor of the room are radiating heat. However, they are also absorbing heat at the same time.

Radiation of heat

When temperature of an object is higher than its surroundings then it radiating more heat than it is absorbing. As a result, its temperature goes on decreasing till it becomes equal to its surroundings. At this stage, the body is giving out the amount of heat equal to the amount of heat it is absorbing.

Absorption of heat

When temperature of an object is lower than its surroundings, then it is radiating less heat than it is absorbing. As a result, its temperature goes on increasing till it becomes equal to its surroundings. The rate at which various surfaces emit heat depends upon the nature of the surface.

Q.No.8 What is Leslie cube? How various surfaces can be compared by Leslie cube? (GRW 2014)

Leslie Cube

A Leslie cube is a metal box having faces of different nature as shown in figure. The four faces of Leslie's cube may be as follows:

- A shining silvered surface
- A dull black surface
- A white surface
- A coloured surface

Hot water is filled in the Leslie's cube and is placed with one of its face towards a radiation detector. It is found that black dull surface is good emitter of heat. The rate at which various surfaces absorb heat also depends upon the nature of those surfaces.

Example

Take two surfaces, one is dull black and the other is silver polished surface with a candle at the middle of the surface. It is fount that:

Black Surface

A dull black surface is a good conductor of heat and its temperature rises rapidly.

Polished Surface

A polished surface is poor absorber of heat as temperature rises very slowly. It is also found that the transfer of heat by radiation is also affected by the surface area of the body emitting or absorbing heat.

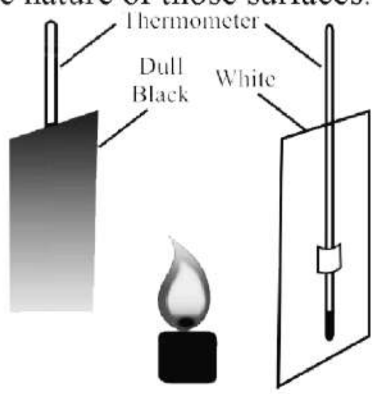

Figure 9.16: A comparison of absorption of radiation.

Area of the surface

Larger is the area, greater will be the transfer of heat. It is due to this reason that large numbers of slots are made in radiators to increase their surface area.

Greenhouse Effect (LHR 2013, GRW 2013)

Q.No.9 What do you know about greenhouse effect? Also explain the global warming.

Light from the Sun contains thermal radiations (infrared) of long wavelengths as well as light and ultraviolet radiations of short wavelength. Glass and transparent polythene sheets allow radiations of short wavelength to pass through easily but not long wavelengths of thermal radiations. Thus, a greenhouse becomes a heat trap.

Radiations from the Sun pass easily through glass and warms up the objects in a greenhouse. These objects and plants give out radiations of much longer wavelengths. Glass and transparent polythene sheets do not allow them to escape out easily and are reflected back in the greenhouse. This maintains the inside temperature of the greenhouse. Greenhouse effect promises better growth of some plants. Carbon dioxide and water also behave in a similar way to radiations as glass or polythene.

Global Warming

Earth's atmosphere contains carbon dioxide and water vapors. It causes greenhouse effect and thus maintains the temperature of the Earth. During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to greenhouse effect. This phenomenon is known as global warming.

9.5 APPLICATION AND CONSEQUENCES OF RADIATIONS

Q.No.10 Explain the application and consequences of Radiations.

Different objects absorb different amounts of heat radiations falling upon them reflecting the remaining part. The amount of heat absorbed by a body depends upon the colour and nature of its surface.

Black Surface

A black and rough surface absorbs more heat than a white or polished surface. Since good absorbers are also good radiators of heat. Thus, a black coloured body quickly absorbing heat reaching it during a sunny day and sunny day and also cools down quickly by giving out its heat to its surroundings. The bottoms of cooking pots are made black to increase the absorption of heat from fire.

White and Polished Surface

Like light rays, heat radiators also obey laws of reflection. The amount of heat reflected from an object depends upon its colour and nature of the surface. White surfaces reflect more than coloured or black surfaces. Similarly, polished surfaces are good reflectors than rough surfaces and reflection of heat radiations is greater from polished surfaces. Hence, we wear white or light coloured clothes in summer which reflect most of the heat radiation reaching us during the hot day. We polish the interior of the cooking and hot pots for reflecting back most of the heat within them.

Unit 9: Transfer of Heat

Multiple Choice Questions

1. **Ice is an:**
   (a) Good conductor **(b)** Bad conductor
   (c) Perfect Conductor **(d)** None
2. **There are ------------ methods of transmission of heat:**
   (a) 1 **(b)** 2
   (c) 3 **(d)** 4
3. **Which of the following is best for insulation?**
   (a) Glass **(b)** Air
   (c) Brass **(d)** Fiber glass
4. **Transmission of heat from one body to another body by the interaction of atoms and electrons:**
   (a) Conduction **(b)** Convection
   (c) Radiation **(d)** All of above
5. **Transfer of heat by the actual movement of molecules:**
   (a) Conduction **(b)** Convection
   (c) Radiation **(d)** All of above
6. **Geysers work on the principle of:**
   (a) Conduction **(b)** Convection
   (c) Radiation **(d)** All of above
7. **Transmission of heat by waves without affecting medium on its way:**
   (a) Conduction **(b)** Convection
   (c) Radiation **(d)** All of above
8. **Ventilation in our houses is only possible due to:**
   (a) Conduction **(b)** Convection
   (c) Radiation **(d)** All of above
9. **Heat from sun reaches us by:**
   (a) Conduction **(b)** Convection
   (c) Radiation **(d)** All of above
10. **Water is a:**
    (a) Good conductor **(b)** Poor conductor
    (c) Super conductor **(d)** Insulator
11. **Feathers of the birds are:**
    (a) Conductor **(b)** Semiconductor
    (c) Insulators **(d)** None of them
12. **Land and sea breezes are due to:**
    (a) Conduction **(b)** Convection
    (c) Radiation **(d)** All of them
13. **Global warming in the world is due to:**
    (a) Greenhouse effect **(b)** Land and sea breezes
    (c) Radiation **(d)** None of them
14. **Black surfaces are ------------ emitter:**
    (a) Best **(b)** Good

(c) Worst **(d)** Poor

15. Shinning silvered surfaces are ----------- reflector:

(a) Best **(b)** Good

(c) Worst **(d)** Poor

16. Coloured surfaces are ------------- absorber

(a) Best **(b)** Good

(c) Worst **(d)** Poor

17. The gases in the Earth's atmosphere, which causes the greenhouse effect:

(a) Carbon dioxide **(b)** Water vapors

(c) Both a & b **(d)** None of them

18. Which one is (are) the insulator (s)?

(a) Cork **(b)** Cotton

(c) Rubber **(d)** All of them

19. Movement of water on heating is shown by the crystal of:

(a) Sodium chloride **(b)** Potassium permanganate

(c) Calcium carbonate **(d)** None of them

ANSWER KEY

1	b	2	c	3	b	4	a	5	b
6	b	7	c	8	b	9	c	10	c
11	b	12	b	13	a	14	a	15	a
16	b	17	c	18	d	19	b		

Unit 9: Transfer of Heat

Problems

9.1 The concrete roof of a house of thickness 20 cm has an area 200 m^2. The temperature inside the house is 15^0 C and outside is 35^0 C. find the rate at which thermal energy conducted through the roof. The value of k for concrete is 0.65 $Wm^{-1}K^{-1}$.

Given Data

Thickness of the roof = L = 20 cm = 0.2 m

Area of the roof = A = 200 m^2

Temperature outside the house = $T_1 = 35^0$ C = (35 + 273) K = 308 K

Temperature inside the house = $T_2 = 15^0$ C = (15 + 273) K = 288 K

Coefficient of thermal conductivity = k = 0.65 $Wm^{-1}K^{-1}$

Required

Rate of conduction of energy through the roof = Q/t = ?

Solution

As we know that

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{kA(T_1 - T_2)}{L}$$

By putting the values, we have

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{0.65 \times 200 \times (308 - 288)}{0.2}$$

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{130 \times 20}{0.2}$$

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{2600}{0.2}$$

$$\text{Rate of flow of heat} = \frac{Q}{t} = 13000\ Js^{-1}$$

Result

Rate of conduction of energy through the roof = Q/t = 13000 Js^{-1}

9.2 How much heat is lost in an hour through a glass window measuring 2.0 m by 2.5 m when inside temperature is 25^0 C and that of outside is 5^0 C, the thickness of glass is 0.8 cm and the value of k for glass is 0.8 $Wm^{-1}k^{-1}$?

Given Data

Area of the window = A = 2.0 m x 2.5 m = 5.0 m^2

Thickness of the glass = 0.8 cm = 0.0008 m

Temperature inside the window = T_1 = 25° C

Temperature outside the window = T_2 = 5° C

Coefficient of thermal conductivity = k = 0.8 $Wm^{-1}K^{-1}$

Required

Heat lost through the glass = Q = ?

Solution

As know that

$$Q = \frac{kA(T_1 - T_2)t}{L}$$

By putting the values, we have

$$Q = \frac{0.8 \times 5 \times (298 - 278) \times 3600}{0.008}$$

$$Q = \frac{4 \times 20 \times 3600}{0.008}$$

$$Q = \frac{288000}{0.008}$$

$$Q = 36000000 \text{ J}$$

$$Q = 3.6 \times 10^7 \text{ J}$$

Result

Heat lost through the glass = Q = 3.6 x 10^7 J